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INVESTIGATION OF MINING RELATED POLLUTION REDUCTION ACTIVITIES AND ECONOMIC INCENTIVES IN THE MONONGAHELA RIVER BASIN

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Beaver, Pennsylvania

April 1975

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The study provides information on feasible economic incentives which will encourage the private sector and others to undertake environmental improvement activities on abandoned and active mines in the Monongahela River Basin. The undertaking of these activities with the recovery of restoration expenses at a profit will help lessen the crushing pollution abatement cost to government in the basin. Major subjects discussed are: controlling surface water infiltration in underground mines; coal waste utilization; engineering properties of coal waste; land reclamation and recovery of coal reserves from partially worked out mines.

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INVESTIGATION OF MINING RELATED POLLUTION REDUCTION ACTIVITIES AND ECONOMIC INCENTIVES IN THE MONONGAHELA RIVER BASIN

ARC CONTRACT NO.
72-89/RPC-707

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APRIL, 1975

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PREFACE

This study is one of a series of reports being prepared for the Appalachian Regional Commission for the development of an overall environmental pollution abatement plan for the Monongahela River Basin with special attention to mine drainage. The Basin is an 18-county area encompassing parts of Appalachian West Virginia, Pennsylvania and Maryland.

These studies are being performed under an agreement between the Environmental Protection Agency and the Commission and are part of a larger EPA effort to deal with elimination and control of mine drainage within the watershed. The Commission's major responsibility in this interagency effort is to evaluate the economic development impacts of mine drainage and other pollution abatement which will include for planning purposes those engineering studies necessary to determine cost effectiveness among possible alternative approaches and to assess the full range of activities required to improve the environment within the Basin consistent with water and land use objectives. It is felt that if pollutants and other environmentally degrading problems can be alleviated, other public and private investments will provide greater opportunities to improve the economy of the Basin. The results of these studies then should suggest courses of action for selecting priorities for environmental and associated projects to Federal, State, and local decision-makers and the private sector as well as clarifying the Basin's potential for economic development.

Coal Recovery From An Old Abandoned Refuse Bank. Westmoreland County, Pennsylvania

INVESTIGATION OF MINING RELATED POLLUTION REDUCTION ACTIVITIES AND ECONOMIC INCENTIVES IN THE MONONGAHELA RIVER BASIN

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EXECUTIVE SUMMARY

The Appalachian Regional Commission (ARC), in conjunction with the Environmental Protection Agency (EPA) has been given a most challenging assignment by the United States Congress. The Commission is to prepare a comprehensive environmental improvement program aimed at developing the economic potential of the Monongahela River Basin. Emphasis must be given to results achievable from the abatement of abandoned mine drainage pollution.

One of the program tasks is to provide information on possible pollution reduction activities which private industry might profitably undertake. The ARC feels there are many economically sound projects which the private sector might perform at a profit which will help lessen the crushing pollution abatement cost to government in the basin. The Commission engaged Michael Baker, Jr., Inc. to perform a study which would provide such information under ARC Contract No. 72-89/RPC-707 titled "Investigation of Mining Related Pollution Reduction Activities and Economic Incentives in the Monongahela River Basin."

The objective of the study was to develop or discover feasible economic incentives which would encourage the private sector to undertake environmental improvement activities on abandoned and active mining operations. The undertaking of these activities would result in pollution abatement and the recovery of restoration expenses at a profit. The results of the study indicate that most of the activities investigated can be economic incentives. Other activities indicate a definite potential for being economic incentives.

Controlling surface water infiltration into underground mines should be of significant benefit to coal mine operators when mine drainage discharges are moderately to highly acid. The concurrent reclamation of partially worked out deep and/or surface mines and the recovery of remaining coal reserves as initiated by the Commonwealth of Pennsylvania can decrease the overall cost of reclamation. The coal credit can vary widely, but sometimes this reclamation procedure may be the only practical method.

The combining of land reclamation at abandoned mines with the removal of coal refuse piles is a viable reclamation procedure. There are many areas in the Monongahela River Basin where environmental improvement programs of this type would enhance the economic prospects of the area. Case histories of several relevant projects are presented illustrating the feasibility of performing projects of this nature. These projects demonstrate the potential for: 1) turning mining wastelands into valuable real estate, 2) utilizing coal refuse for development of level land in areas where land sells at a premium, 3) surface mining methods which create relatively level land for future residential, commercial and institutional use in areas of steep terrain, 4) developing strip mines into recreational areas, and 5) daylighting mined areas to eliminate mine drainage, thereby improving the

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environment and land values. Certain provisions of the proposed "Surface Mining Control and Reclamation Act of 1975" would greatly increase opportunities to perform projects of this type. Section 405 of the proposed legislation is a powerful tool for acquisition of interest in land or mineral rights. The legal framework for dealing with such problems as acquiring legal property rights or easements has hampered mined land reclamation for years.

The prospects of reclamation and revegetation of mined lands for profitable timbering and/or pulpwood industry does not appear very promising. It should be recognized there are vast differences between a forest products industry operation on unmined land and one on mined land. A typical forest products operation consists of well managed large land holdings in an area which has been forest for possibly thousands of years without the ground being disturbed. In the Monongahela River Basin, surface mines are not relatively large, although there may be many in one geographical area. Successful forestation depends on the physical and chemical properties of the spoil or coal refuse material. The amount of alteration of these properties necessary for successful plant growth will greatly affect the cost of the project. Selection of tree types suitable for a mined land environment appears to be limited and in most cases the trees will compete with the establishment of the necessary vegetative ground cover for survival. Depending on the type of forest and proper management, large economic returns cannot be expected for a period of 25 to 40 years on mined lands. There is a high initial investment without profit until this time period.

The economic potential for utilization of waste coal with relatively high Btu content for power production either directly or by blending with higher grade coals is very promising. The coal shortage of last winter coupled with increased production costs for current mined coal have made the processing of coal from waste disposal sites very attractive and a number of disposal areas are now being processed for coal recovery. Information developed in this study strongly infers that material from a high percentage of coal waste disposal sites in the Monongahela River Basin can be burned in new, modified or existing combustion processes.

The utilization of coal mine waste for landfill and embankment material is a viable economic incentive if projects are properly designed, constructed and maintained. The utilization of this material in construction can decrease earthwork costs and increase land values at the reclaimed site. Two sections of the report present the results of laboratory investigations on the engineering properties of bituminous coal mine waste performed in 1972 and 1974 in the soils laboratory of Michael Baker, Jr., Inc. Samples were collected from disposal sites throughout the Monongahela River Basin and the tests include soil index properties, moisture-density relationship, compaction and strength characteristics, degradation characteristics, permeability and chemical parameters. It was concluded from the test results that coal refuse is a better material for construction than many accepted soil materials.

The economic potential for using raw coal waste material and fly ash in the manufacture of bricks, blocks, lightweight aggregate and other products has become more attractive in the last few years. Great Britain is now using large tonnages of coal waste and fly ash in the manufacture of useful products and plants using these materials are beginning to appear more frequently in the United States. Raw coal waste and fly ash have been used for mine subsidence control on a number of projects in recent years.

A potential utilization of coal refuse which may be very promising and a feasible economic incentive is the extraction of alumina. The total annual domestic requirements for aluminum may increase anywhere from five to ten times the present level by the year 2000. It has been predicted that industry by 1980 or shortly afterwards may begin processing low grade bauxites, clays and shales, and other materials to meet the demand. High grade aluminum sulfate has been produced from coal refuse as early as 1962 and an American coal company gave serious consideration to a commercial venture to extract alumina. Renewed interest in this field of coal refuse utilization may be very timely, particularly since unstable international conditions make foreign imports unreliable.

In performing this study, a great deal of emphasis has been placed on coal waste utilization because it is believed this is one of the areas which offers the most promise for coal operators and others to undertake environmental improvement activities at a profit. What to do with coal waste and how to limit waste in mining and preparation of coal are major issues facing the coal industry today. With coal once again "King," the problem of waste disposal will become even greater as we strive toward energy independence by 1985, if solutions are not found. Utilization of abandoned coal waste deposits and markets for waste from current mining operations will go a long way in solving the coal waste disposal problem.

INTRODUCTION

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INTRODUCTION

OBJECTIVES AND SCOPE OF REPORT

The Appalachian Regional Commission (ARC), in conjunction with the Environmental Protection Agency (EPA) has been given a most challenging assignment by the United States Congress. The Commission is to prepare a comprehensive environmental improvement program aimed at developing the economic potential of the Monongahela River Basin. Emphasis must be given to results achievable from the abatement of abandoned mine drainage pollution.

One of the program tasks is to provide information on possible pollution reduction activities which private industry might profitably undertake. The ARC feels there are many economically sound projects which the private sector might perform at a profit which will help lessen the crushing pollution abatement cost to government in the basin. The Commission engaged Michael Baker, Jr., Inc. to perform a study which would provide such information under ARC Contract No. 72-89/RPC-707 titled "Investigation of Mining Related Pollution Reduction Activities and Economic Incentives in the Monongahela River Basin."

The objective of this study therefore is to develop or discover feasible economic incentives for coal mine operators and others to undertake environmental improvement activities on : 1) existing mining operations to reduce operation and restoration expenses; and 2) abandoned mines to recover expenses with a profit.

Michael Baker, Jr., Inc. was required through appropriate federal, state and local governments and the private sector, to determine the historical extent of land reclamation and the reuse of waste coal generated by coal mining operations in the United States and foreign countries. Where such activities were undertaken and satisfactorily completed, a brief outline of the project with pertinent details related to expenses versus receipts, both actual and projected, were to be presented if possible. The study area included the entire Monongahela River Basin.

To provide initial directions as to the types of activities that should be explored for development of economic incentives, the ARC suggested the following list of items as a guide to what should be covered in the study:

1. Identify active deep coal mines having a potential for percolation reduction where control programs could be initiated to reduce surface water penetration into the mine workings. Aside from benefits received from reduced mine drainage discharges into receiving streams, additional benefits could accrue to the operators in the form of reduced operating costs. The reduction of unwarranted amounts of water in the active mines could provide savings in the way of reduced pumping costs and

could extend the life of facilities such as pumps, piping and other equipment exposed to acid water as well as reducing mine drainage treatment costs. Filling of surface depressions caused by mine subsidence and reclamation of surface mines were examples of the types of activity which should be considered. The study should also include estimated site improvement costs and projected savings to coal mine operators as well as guidelines which could be used in undertaking such activities.

2. Investigate the concurrent reclamation of partially worked out deep and/or surface mines and the recovery of remaining coal reserves as initiated by the Commonwealth of Pennsylvania. Fiscal incentives and administrative practice have been utilized to accomplish pollution abatement via this mechanism. An evaluation of the prospects of this restoration approach along with legal and policy matters should be included in the study. The physical situations influencing consideration of this reclamation/mining procedure should be discussed.

3. Investigate the prospects of reclamation of mined lands for profitable timbering and/or pulp wood industry sufficient to encourage mining companies or others to restore mined lands for these uses.

4. Investigate the economic potential for utilization of waste coal with relatively high Btu content for power production either directly or by blending with higher grade coals. The following tasks should be accomplished as part of this item:

    A. Locate sources of waste coal within the basin on a suitable map and in tabular form present for each coal waste area available information on location, ownership, estimated area and volume of waste, and other pertinent information;

    B. Estimate the potential acid mine drainage reduction if these potential fuel sources are mined;

    C. Through communication with power producers define what problems (air pollution, firing characteristics, and others) would be encountered with the use of blended fuel and how these problems may be overcome;

    D. Determine how the ARC and other governmental agencies can encourage disposal of coal waste with relatively high Btu contents for the multipurpose benefits of pollution reduction, resource recovery, land reclamation and economics;

    E. Investigate the potential for the economic utilization of waste coal within the basin based on information developed in the previous tasks.

5. Explore the economic potential for utilization of raw coal waste material as subsidence area fill and in the manufacture of bricks, concrete block, light weight aggregate and other products. Data on utilization for these uses should be collected and its applicability to the Monongahela River Basin appraised.

6. Investigate the prospects of utilizing coal waste as a source of construction material for embankments and fills. A wealth of information has been accumulated in the last few years, mostly in the United Kingdom, on the physical and chemical characteristics of coal waste and a number of projects have been designed and constructed using both burnt and unburnt coal waste material. Data on the European experience should be collected and its applicability to the United States, particularly the Monongahela River Basin, appraised.

7. After a review of data compiled by government agencies and private industry, identify sites where it appears the combining of land reclamation at abandoned mines with the removal of coal waste piles is feasible, thereby generating "new" useful land and utilizing waste as fill. As part of this task consideration should be given to the following:

   A. The special conditions or procedures required for utilization of coal waste as fill;

   B. The possibility of mining the remaining coal in back of the highwall of old contour strip mines with placement of all or part of the overburden on land within reasonable haul distance as compacted fill for site development or similar use;

   C. Project costs and estimated returns for selected sites, if this information is readily available or can be estimated;

   D. The kinds of developments that should be considered, such as, industrial parks; construction of dams and access roads for recreational lakes; fill for modular unit development (trailer courts), low lying land subject to frequent flooding, and areas affected by subsidence; secondary airports; parking areas for mass transit systems; and disposal sites for municipal, industrial solid wastes and automobile hulks;

   E. Guidelines to encourage projects of this nature.

MODIFICATIONS OF THE STUDY PLAN

It was understood the initial directions covering types of activities to be explored for the development of economic incentives was not complete. The study was to extend, combine and/or modify the initial directions input in order to generate a report that would provide as thorough a coverage of the subject as possible within the funding available. The subject was broad and success would depend upon the availability of information for some tasks and, the interest and cooperation of government agencies and the private sector. For some of the tasks, there was very little factual information. Most of the organizations and individuals that were contacted cooperated and showed an interest in the study; even when they believed it was not practical to attempt an activity because of the lack of reliable domestic case history experience, such as, in the case of using coal waste as a construction material.

Very early in the study it became apparent it would be difficult to convince government agencies that the utilization of coal waste for construction was safe, environmentally sound, and practical. The fear of combustion of the material and possible acid discharges from a completed structure were the reasons given for not wanting to participate in this activity. Also, little information existed on the energy value of coal waste piles and slurry ponds. Therefore, it would be necessary to develop information on the engineering properties and composition of coal waste deposits in the Monongahela River Basin.

The study was modified to include sampling of coal waste disposal sites. Twenty sites, scattered throughout the basin, were chosen in 1972 to be representative of the over 300 disposal sites located by the use of U. S. Geological Survey 7-1/2 Minute Topographis Quadrangles, field reconnaissance, and information supplied by EPA, Army Corps of Engineers and the U. S. Bureau of Mines. Suitable engineering properties tests were performed on the samples and a proximate analysis was determined for each sample.

Very little knowledge existed in the United States in 1972 on the utilization of coal waste in construction, particularly large volume applications, such as using this material for embankment and fill construction. A literature search revealed a number of foreign publications, mainly from Great Britain, discussing the utilization of coal waste for these purposes. Therefore, it was determined it would be profitable to make a trip to Great Britain to obtain at first hand the latest information on their experience in using this material in construction. A member of the staff met with officials of the National Coal Board (NCB) and visited several areas in England where he observed construction and design practices. The ARC, through Dr. David R. Maneval, facilitated this phase of the study by writing letters of introduction to principal investigators in Great Britain.

In order to take advantage of the unique qualifications and expertise of Mr. Joseph W. Leonard, the ARC granted permission for a subcontract of part of the task requiring an investigation of the economic potential for the utilization of waste coal with relatively high Btu content for power production either directly or by blending with higher grade coals. The results of this study appear in Section V of the report under the title "Waste Coal Reclamation" by J. W. Leonard and W. F. Lawrence.

Most of the study was performed in 1972 and early 1973, but additional funding was made available by the ARC in 1974 for an investigation of recent projects in Pennsylvania where coal refuse banks were being used in engineering construction or being processed for coal recovery. As part of this supplement, four additional coal waste disposal sites were sampled in October, 1974 and compositional analysis and engineering properties tests performed. Some of the sections of the study completed previously have been updated to incorporate the latest information and technological advances.

FORMAT OF THE REPORT

The main body of the report is divided into ten individual sections and each section deals with a separate activity performed as part of the overall study. Appendices are included at the back of the report which tabulate the data on the inventory of coal refuse banks and the location of limestone mining operations in the Monongahela River Basin. Three map sheets are also included at the back of the report covering the Monongahela River Basin and they present:

1. Index of Topographic Maps and Sub-Basins
2. Location of Coal Refuse Banks and Power Plants
3. Outcrop Map of the Greenbrier Limestone

For convenience and easy reference, there is a general "Table of Contents" at the beginning of the report and each section has a detailed "Table of Contents" which lists tables and figures found in the section.

A RENEWED INTEREST IN UTILIZING COAL WASTE

Waste from coal mining is not a recent problem, but increased mining activity and the accumulation of coal waste deposits for one hundred fifty years or more have made the problem more noticeable and acute. It has been a serious problem since the early 19th century. In the early days much of the waste from coal mining, particularly in the anthracite fields, could be attributed to a lack of markets for the finer size coals and primitive methods of mining and coal preparation. Almost from the inception of coal mining in the United States, official and private reports, technical publications and editorials have been concerned with this waste. Many technological advances have been made through the years which improved the efficiency of mining methods and coal preparation and these led to a reduction in the percentage of coal ending up on the refuse pile. Markets were developed for the finer coals and as improved methods of preparation were developed, many an old refuse pile was reworked for part of its coal content.

Numerous studies have been performed with the object of utilizing coal waste and this material has been used in such products as building blocks, bricks, lightweight aggregate and as compressed coal, a form of fuel. Larger volumes have been used for underground stowage to prevent mine subsidence or as support during deep mining so that a larger percentage of the coal could be won. Additional volumes have been used locally as landfill and red dog (burnt refuse), the end product of burning refuse banks, has been acceptable as a material in highway construction. In spite of this usage of coal waste, it is estimated over three billion short tons presently lie on the surface in coal mining areas of the United States. The extensively mined Monongahela River Basin can be considered to have more than its fair share.

It is only within the last ten years that a concerted effort has been made to alleviate the coal waste disposal problem by emphasizing the potential for using this material in applications where large volumes are required. Unfortunately it took two disasters, one in Great Britain, the other in the United States, for this to come about.

Interest in utilization of coal waste for major construction projects in Great Britain was prompted by the Aberfan disaster in Wales (October, 1966) where a coal refuse pile slid onto a school killing many children. Sliding coal refuse piles had plagued Wales and other coal mining areas in Great Britain for many years. Several investigations into the cause of coal refuse pile failures had been performed previously, but it took a disaster of this magnitude before a concerted effort was made by government and the public to prevent a future occurrence of an Aberfan tragedy. In addition to the many investigations on coal waste pile stability and design performed by individuals and organizations following Aberfan, a cooperative research effort by the NCB, the Ministry of Transport through the Road Research Laboratory, and others led to the utilization of large volumes of coal waste in construction of highways, landfills, dams and other uses. Within a few years Great Britain became the acknowledged leader in coal waste utilization technology.

It is ironic that a disaster of a similar nature had to occur in the United States before government and the public were spurred to action. Just as in Great Britain, the Appalachian Region had been plagued for many years with coal waste pile failures, but the failures occurred in isolated areas with little loss of life and property damage. The failure of a coal waste impoundment on Buffalo Creek in West Virginia (February, 1972) which took many lives and caused great property damage, not only led to numerous studies on the engineering properties and design of coal waste piles and embankments, stricter enforcement of existing regulations and promulgation of additional legislation, but it also sparked an interest in the utilization of coal waste for major construction projects.

Immediately after the Buffalo Creek disaster, a Department of Interior task force was organized to make a rapid study of mine waste impoundments and coal waste dam hazards throughout the Appalachian Region. Studies were performed by the U. S. Army Corps of Engineers, U. S. Geological Survey, U. S. Bureau of Mines, state agencies, citizen groups and engineering consultants. These initial studies resulted in an interest in large scale utilization of coal waste in engineering construction and an awareness of European technology in this field.

In 1972, the two principal authors of this study, in conjunction with another project, presented a paper on the utilization of coal mine refuse. This paper was presented to the Environmental Quality Board, Pennsylvania Department of Environmental Resources, at a public hearing on coal waste disposal regulations and it stressed the importance of utilizing coal refuse for large volume applications, such as landfill and embankment construction, and as a source of low cost fuel for power generation. Copies of this paper were given to individuals in the Pennsylvania Department of Transportation and the West Virginia Department of Highways in the hope of interesting these agencies in the potential of utilizing coal waste as fill and embankment material in highway construction. Copies were also given to individuals in the Soil Conservation Service, Department of Agriculture, the Corps of Engineers, EPA and industry in the hope they would consider the utilization of coal refuse in some of their activities.

When the section titled "Laboratory Investigation of the Engineering Properties of Bituminous Coal Mine Refuse" was completed in early 1973, copies were given to individuals in the above government agencies and others interested in the utilization of coal waste in construction. This was done at the request of the ARC in order to make the data available as soon as possible.

A number of letters were also sent to state and federal agencies following the Hurricane Agnes disaster of 1972 which caused widespread devastation in the northeastern United States in an attempt to encourage these agencies to consider the utilization of coal mine refuse in the construction of flood control structures and as a fill for low lying areas subject to frequent flooding.

The work of Dr. Maneval, Science Advisor for the ARC, in encouraging the utilization of coal mine waste for major construction projects in the United States should not be overlooked. He has long been a staunch advocate of the utilization of coal waste. As a result of his broad experience in the environmental aspects of coal mining, his trips to Europe to study mining practices, environmental controls and waste utilization, and contacts with the NCB and other foreign agencies, he was probably the first in the United States to be cognizant of the significance of the European experience in using coal waste for the construction of major projects. His assistance in the coal waste utilization phase of the study has been invaluable. He has also actively participated in our efforts to encourage government agencies and others to utilize this material in construction.

In the spring of 1973 a cooperative agreement was worked out in Pennsylvania between the State Departments of Transportation (PennDOT) and Environmental Resources (DER) for the utilization of coal waste in highway construction. As a result of the agreement about 1.5 million cubic yards of coal refuse were used in embankment construction of the Cross Valley Expressway at Forty Fort, Luzerne County, in the Northern Anthracite Coal Field of eastern Pennsylvania. The percentage of unburnt and burnt (red dog) refuse used in embankment construction is estimated to be about equal in proportion.

A second project utilizing coal waste proposed for the Northern Anthracite Coal Field is a section of the Lackawanna Valley Expressway between Scranton and Carbondale, Lackawanna County, Pennsylvania. This project is in the preliminary design stage, but it is estimated anywhere from three to seven million cubic yards of coal waste could be used in construction of the highway.

In the bituminous coal region of western Pennsylvania, PennDOT has proposed at least three projects:

1. East of Monesson, Westmoreland County, it has been proposed extinguishing the fire in a burning refuse bank by covering the bank with waste excavation from a nearby roadway cut. An industrial park may be developed in this area.

2. A coal refuse pile near California, Washington County, may be used for highway fill in the flood plain of Pike Run.

3. Two of the larger coal refuse banks in western Pennsylvania, the Revloc banks of the Bethlehem Mines Corporation, near Ebensburg, Cambria County, are proposed for fill and embankment construction in the modernization of Routes 219 and 422. An examination of the banks indicate they may contain up to 50 percent recoverable coal. The banks will be processed for coal before being used for highway construction and it is estimated about four million cubic yards of processed refuse will be available. The Bethlehem Mines Corporation is donating the refuse and they have donated the land upon which the refuse banks lie to the county for development of an industrial park.

EPA in conjunction with West Virginia University and the Monongahela Power Company in 1973 used a coal refuse and fly ash composition in construction of a demonstration parking lot at the EPA Drainage Control Field Station in Crown, West Virginia.

The ARC in 1974 made a grant to the West Virginia Department of Highways which will underwrite, in part, the initial studies by this state on the utilization of coal mine refuse in highway construction.

CONCLUSIONS

Reduction of Surface Water Infiltration into Underground Mines

Reduction of surface water infiltration into underground mines can be an economic incentive to coal mine operators in many cases, particularly in light of the stringent water quality standards established by the federal government. The cost of surface water infiltration control techniques, such as surface mine reclamation, filling subsidence depressions and fractures, lining stream channels and grouting of barriers, should be compared to the cost of collecting and treating the water that has entered the mine environment. Capital and operating costs for collecting water from deep mines do not appear to be significant. The real benefit to the coal operator lies in the reduction of acid mine drainage treatment costs. The quality of infiltrated surface water when it comes in contact with water in the mine environment is a major factor in determining mine drainage treatment cost benefits, but the capital cost projection for a treatment facility may be an incentive in cases where a major reduction in flow is not accompanied by a significant decrease in mine drainage treatment operating cost.

The cost of mine drainage treatment is highly variable and reflects the quality and quantity of flow treated, the type of mine drainage treatment facility, land acquisition and site improvement costs, the type of cost of reagent used in treatment, the detention time for treatment, sludge volume, density, disposal method and other factors.

The water quality improvement and cost benefit will depend on many factors unique to a particular mine situation, but benefits should be significant when the discharge is moderately to highly acid. Before a mine environment is considered for surface water infiltration control techniques, a thorough study should be made of the geological, hydrological, mineralogical, climatological and mining method parameters.

Twenty underground mines were proposed for investigation of surface water infiltration control techniques and a detailed study was made of two mines. There did not appear to be an economic incentive for these techniques at either of the mines, but the studies revealed some interesting data and information useful for further studies of surface water infiltration control and mine drainage treatment methods.

At one mine, a brief study was made of an unusual method of treating highly acid mine drainage. The discharge is used in the coal cleaning process at the preparation plant. The acid water becomes completely neutralized during the cleaning process. It appears fracture fillings of secondary calcite present along cleavage surfaces in the coal and within the binder bed are mainly responsible for this phenomenon. Neutralization has been effective because there is only a small highly acid discharge which is recirculated to insure an adequate supply for coal processing. Complete neutralization occurs because the mine water is aerated at several stages of the preparation process. The physical and chemical conditions at this mine may exist at other mines in the Monongahela River Basin. Therefore, further study of this pollution abatement phenomenon appears warranted.

At the other mine, an overburden thickness of 350 feet was not sufficient to prevent subsidence and fracturing of rock strata during retreat mining. Most of the precipitation which falls within a drainage basin, less that lost to evapotranspiration, infiltrates into the mine workings. As a result, a wide variation in the mine discharge exists depending on climatological conditions. When this section of the mine was designed and laid out, care was taken to minimize acid production and the services of a preeminent authority on acid mine drainage formation and abatement was obtained. The adherence of good drainage practice, which generally followed recommendations of the Ohio River Valley Sanitation Committee (ORSANCO), has shown that mine drainage pollution can be eliminated by proper planning and design. The discharge from the borehole has an average pH of 7.2

The most serious mine drainage pollution problem at this mine was in two other sections where water was infiltrating through the barrier pillar separating the active mining operation from an abandoned flooded mine. The highly acid drainage is pumped to the surface where it is treated. Percolation reduction techniques would require sealing the barrier between the two mines. This does not appear to be practical because the cost would be prohibitive compared to present operating costs and the life expectancy of the mining operation.

Concurrent Reclamation of Partially Worked Out Deep and/or Surface Mines and the Recovery of Coal Reserves

The Commonwealth of Pennsylvania has initiated concurrent reclamation of partially worked out deep and/or surface mines and the recovery of remaining coal reserves for some of its reclamation programs. This work is being performed as part of "Operation Scarlift," a $500 million bond issue for a Land and Water Conservation and Reclamation Fund. Case histories indicate this approach was chosen because acid mine drainage could be more effectively abated by construction of a clay barrier seal along the highwall created by stripping a deep mined area. In areas that had been partially strip mined, additional stripping was performed to extend the surface working into an area of relatively unfractured overburden above the deep mine, thereby reducing or eliminating high rates of surface water infiltration. The strip mining also shortens the length of clay seal needed to effectively hydrologically isolate the remaining deep mined area. The recovery of coal is of secondary importance, although it can decrease the overall cost of reclamation. On one project the coal credit resulted in a project cost reduction of 32.5 percent indicating the benefits that can occur using this reclamation approach.

Concurrent reclamation and coal recovery should be practiced in areas where construction of mine seals and curtain grouting are not practical because physical situations are such that: 1) the mine has numerous openings and/or mining was close to the outcrop, 2) extensive subsidence has occurred and fractured overburden permits ingress of large volumes of surface water into the deep mine workings, and 3) previous strip mining has intercepted deep mine workings and a clay barrier seal along a highwall is the only practical method.

This procedure may be profitable in areas where the overburden thickness is not great. In many old strip mines a few more cuts would have completely stripped a hill, but at the time of the active operation it was not profitable for the coal operator to do this. The recovery of coal from a thin seam of good quality lying above the deep mine seam can increase the coal credit.

Concurrent reclamation and coal recovery is placed in a different perspective if a watershed or regional approach to reclamation is considered. Studies have been made of the effects of mining pollution on a watershed or region, but the interrelationship of reclamation, coal recovery, land use and other factors have barely been taken into consideration. If environmental, mineral resource, economic, land use and political factors are considered, a reclamation procedure which is not attractive as an entity may be very attractive in the overall development plan of a watershed or region. To illustrate the potential of this approach, Browns Creek Watershed, about 2.5 miles south of Clarksburg, West Virginia, is used as an example of what could be accomplished.

Combining of Land Reclamation at Abandoned Mines with the Removal of Coal Waste Piles for the Purpose of Generating "New" Useful Land

A review of data compiled by government agencies and other sources was made in order to identify sites where it appeared the combining of land reclamation at abandoned mines with the removal of coal waste piles would be feasible, thereby generating "new" useful land and utilizing coal waste as fill. The possibility of mining the remaining coal in back of the highwall of old contour strip mines (daylighting) with placement of all or part of the overburden on land within reasonable haul distance as compacted fill for site development or similar use was also considered.

There are many areas in the Monongahela River Basin where environmental improvement programs of this type would enhance the economic prospects of the area. Seventeen general locations were proposed and over 40 kinds of development or activity were considered at these locations, such as recreational dams, industrial parks, highways, airports, fill for various purposes, and the potential for daylighting. The three locations selected for further investigation considered the utilization of coal refuse for an airport extension, a section of the Appalachian Corridor highway, and a flood control-recreational dam.

Case histories of several relevant projects completed, under construction, or proposed in the last few years illustrating the feasibility of land reclamation for the purpose of generating "new" useful land are presented. These projects demonstrate the potential for: 1) turning mining wastelands into valuable real estate, 2) utilizing coal refuse for development of level land in areas where land sells at a premium, 3) surface mining methods which create relatively level land for future residential, commercial and institutional use in areas of steep terrain, 4) developing strip mines into recreational areas, and 5) daylighting mined areas to eliminate mine drainage, thereby improving the environment and land values.

Proposed Federal "Surface Mining Control and Reclamation Act of 1975"

The proposed federal "Surface Mining Control and Reclamation Act of 1975," under Title IV - Abandoned Mine Reclamation, would create a trust fund to be known as the Abandoned Mine Reclamation Fund. If this legislation is passed, funds would be made available for the acquisition and reclamation of land. The Act would greatly increase opportunities to perform projects of this nature. The Secretary of the Department of the Interior would be authorized to use money in the fund to acquire, reclaim and develop mined lands for public recreation use and for suitable industrial, commercial, residential or private recreational development.

Certain provisions of the Act would allow for projects to construct or rehabilitate housing for persons employed in mines or work incidental thereto, persons disabled as a result of such employment, persons displaced by government action, or persons dislocated as the result of natural disasters or catastrophic failures from any cause. The land development may include the construction of public facilities or other improvements including reasonable site work and offsite improvements such as sewer and water extensions which the Secretary determines necessary or appropriate to the economic feasibility of the project.

In those instances where mine waste piles are being reworked for coal conservation purposes, the incremental costs of disposing of the wastes from such operations by filling voids and sealing tunnels may be elegible for funding.

Grants would be made to States on a matching basis to encourage the acquisition of abandoned and unreclaimed lands within their boundaries for transfer to the Secretary of the Department of the Interior for reclamation.

The Secretary of Agriculture, utilizing the services of the SoilConservation Service, would be authorized to enter into agreements with landowners to provide for the control and prevention of erosion and sediment damages from unreclaimed mined lands, and to promote the conservation of soil and water resources of unreclaimed mined lands and lands affected by mining.

Possibly one of the most important provisions of the proposed Act is Sec. 405(a)(1) which states, "The Congress hereby declares that the acquisition of any interest in land or mineral rights in order to eliminate hazards to the environment or to the health or safety of the public from mined lands, or to construct, operate, or manage reclamation facilities and projects constitutes acquisition for a public use or purpose, notwithstanding that the Secretary (Department of the Interior) plans to hold the interest in land or mineral rights so acquired as an open space or for recreation, or to resell the land following completion of the reclamation facility or project."

When the Secretary cannot negotiate an agreement with the owner of interest in land or mineral rights, he can request the Attorney General to file a condemnation suit and take interest or right following a tender of just compensation awarded by a jury to such person. If the Secretary determines that time is of the essence because of the likelihood of continuing or increasingly harmful effects upon the environment which would substantially increase the cost or magnitude of reclamation or continuing or increasingly serious threats to life, safety, or health, or to property, the Secretary may take such interest or rights immediately upon payment by the United States either to such person or into a court of competent jurisdiction of such amount as the Secretary shall estimate to be fair market value of such interests or rights. Any further amount that may be subsequently awarded by a jury, with interest from the date of taking, shall be paid to such person [Sec. 405(a)(3)]. When the Secretary cannot determine which person or persons hold title to such interest or rights, he can request the Attorney General to file a condemnation suit, and give notice, and may take such interest or rights immediately upon payment into court of such amount as the Secretary shall estimate to be the fair market value of such interest or rights. Within six years of the time of taking, if a person or persons establishes title, payment will be made along with any further amount that may be agreed to pursuant to negotiations or awarded by a jury. After six years the payment shall revert to the Secretary and be deposited in the reclamation fund [Sec. 405(a)(4)].

Section 405 is a powerful tool for acquistion of interest in land or mineral rights either by negotiation or condemnation, or for acquiring interest or rights where ownership is unknown. The legal framework for dealing with such problems as acquiring legal property rights or easements has hampered mined land reclamation for years, and many a project had to be shelved because these problems appeared unsolvable.

Prospects of Reclamation and Revegetation of Mined Lands for Profitable Timbering and/or Pulpwood Industry

The prospects of reclamation and revegetation of mined lands for profitable timbering and/or pulpwood industry were investigated. As an economic incentive for coal mine operators or others in the Monongahela River Basin, this activity is not promising. It should be recognized there are vast fifferences between a forest products industry operation on unmined land operated for profit and one developed on mined land. A typical forest products operation consists of well managed large land holdings with tracts connected or in proximity to each other. Many operations cover hundreds of square miles. In the Monongahela River Basin, surface mines are not relatively large, although there may be many in one geographical area.

A typical forest products operation is in an area which has been a forest for possibly thousands of years without the ground surface being disturbed. Soil conditions are suitable for the types of trees growing and a forest mat has developed which is not disturbed during harvestation. There is no difficulty in reforesting the area after timbering either by direct seeding or the mechanical planting of seedlings. The chemical properties such as acidity, total soluble salts, and soil nutrients are in balance. The forest mat composed of organic material serves as the nutrient source which is supplemented by the organic life of the forest. The operation is large enough and the age of the trees are variable enough that in a well managed operation there is selective removal of timber.

Successful forestation of mined land is dependent upon the physical and chemical properties of the spoil or coal refuse. The amount of alteration of these properties necessary for successful plant growth will greatly effect the cost of the project. Selection of tree types suitable for a mined land environment appear to be limited and in most cases will compete with the necessary ground cover for survival.

The high initial investment and yearly operating costs coupled with the length of time prior to marketability of the product make annual income minimal, if existant at all. Profit realization will not occur until harvestation begins. Depending upon the type of forest and proper management, large economic returns can be realized annually after about 20 years, but a period of 25 to 40 years is more realistic for mined lands. Reforestation of surface mines of large areal extent may be profitable, but this situation does not exist in the Monongahela River Basin.

Economic Potential for Utilization of Waste Coal with Relatively High Btu Content

The economic potential for utilization of waste coal with relatively high Btu content for power production either directly or by blending with higher grade coals is very promising. The coal shortage of last winter coupled with increased production costs have made the reworking of coal refuse banks and the recovery of coal from preparation plant slurry settling ponds attractive. A review made in October, 1974 of surface mining permits issued by the Pennsylvania Department of Environmental Resources for operation of abandoned coal waste disposal sites indicated there were at least 17 active coal recovery operations in the Bituminous Region and 35 operations in the Anthracite Region of Pennsylvania. Proximate analysis tests performed on samples from a number of coal waste disposal sites in the Monongahela River Basin indicate many waste banks and slurry ponds are suitable for coal recovery. The information strongly infers that material from a high percentage of coal refuse disposal sites in the basin could be burned in new, modified or existing combustion processes to produce useful power with the simultaneous benefit of converting unsightly disposal areas to greatly reduced quantities of more readily utilized ash. An inventory of coal waste disposal areas is presented in Appendix A and a map shows the location of major sites in the Monongahela River Basin.

Utilization of Coal Mine Waste for Landfill and Embankment Material and Laboratory Investigations of the Engineering Properties of Bituminous Coal Mine Refuse

The utilization of coal mine waste for landfill and embankment material is a viable economic incentive if projects are properly designed, constructed and maintained. The utilization of this material in construction can not only reduce earthwork costs, but can increase land values at the reclaimed refuse disposal sites. Two sections of this report present laboratory investigations of the engineering properties of bituminous coal mine refuse performed in the soils laboratory of Michael Baker, Jr., Inc.

The first investigation performed in 1972 concentrated on testing samples collected from disposal sites throughout the Monongahela River Basin. The soils engineering tests were modified for coal waste using procedures and methods developed by the National Coal Board and the Road Research Laboratory of Great Britain. The tests included soil index properties, moisture-density relationship, compaction and strength characteristics, and chemical parameters. Based on the laboratory test results it was concluded: 1) coal refuse is a better material for construction than many accepted natural soil materials, 2) the air void content of coal refuse can be greatly reduced thereby decreasing permeability and the potential for combustion by compaction to the maximum dry density determined by the Standard Proctor Test, 3) coal refuse has adequate strength if the material is properly compacted, 4) specific gravity of coal refuse is a very useful criteria as it is not only useful for determining engineering properties, but can be used for estimating compositional parameters, and 5) design considerations should consider water pollution control and provisions for protection of concrete and metal structures.

The second investigation performed in late 1974, on samples collected from four refuse disposal sites in southwestern Pennsylvania, concentrated on degradation characteristics, percent air void and porosity versus density and moisture content, strength and compressibility characteristics, and permeability of coal refuse in terms of applied static pressures. Conclusions reached based on the laboratory test results obtained in this study were: 1) although weathering and compaction both contribute to the degradation of coal refuse, the extent of degradation caused by weathering and compaction is about the same, 2) the breakdown of mine waste upon compaction is quite pronounced when the compaction energy increases from about 5,000 to 10,000 ft.-lbs./cu. ft. and little additional breakdown occurs when energy is increased from 10,000 to 20,000 ft.-lbs./cu. ft., 3) the air void content is generally 5 percent or less when mine waste is compacted to the maximum dry density determined by the Standard Proctor Test, 4) the compressibility of mine waste increases substantially with slight decrease in dry density, 5) CBR and triaxial tests indicate coal refuse when properly compacted should provide adequate strength for use in landfill, embankment and pavement subgrade, and 6) coal refuse should have a low permeability or be practically impermeable if compacted to a density close to the maximum dry density determined by the Standard Proctor Test, and the coefficient of permeability also decreases substantially with increasing static pressure.

Economic Potential for the Utilization of Coal Waste and Fly Ash for Bricks, Concrete Block, Lightweight Aggregate and Subsidence Area Fill

Fly ash was included in the study of the economic potential for utilization of raw coal waste material as subsidence area fill and in the manufacture of bricks, concrete block, lightweight aggregate and other products because it is in competition with coal waste for these uses and it is the end product of burning coal in coal fired power plants. Bricks have been manufactured from coal waste in Europe since the 1950's and Great Britain reported profits before interest on coal waste brick manufacturing of about one million dollars. Pennsylvania State University was successful in manufacturing lightweight aggregate blocks which met ASTM specifications for lightweight aggregates in 1964. The National Coal Board of Great Britain has recently completed a plant for manufacturing lightweight aggregate from coal waste. Over a half a million tons of coal waste will be converted each year to aggregate and an import savings of about four million dollars will be achieved. The blocks made from this aggregate are called Brag blocks and will be used in construction of houses, offices and factories. Investigations into the possibility of manufacturing mineral wool from coal waste have been performed since the late 1930's. Since 1966, West Virginia University has been investigating the feasibility of producing mineral wool from coal ash slags and fly ash. The results indicate there is a definite potential for utilizing coal waste for this product. Coal mine refuse has been extensively used as a subsidence area fill in the Anthracite Region of Pennsylvania.

Potential for Extraction of Alumina from Coal Waste

A potential utilization of coal refuse which may be very promising and a feasible economic incentive is the extraction of alumina. Coal refuse on the average contains 20 to 25 percent alumina. For the immediate future, only bauxite containing in excess of 40 percent alumina will remain the primary raw material source. The U. S. Bureau of Mines (USBM) predicts by the year 2000 the total annual domestic requirements for aluminum may increase anywhere from five to ten times the present level.

The USBM in looking ahead to eventual depletion of domestic reserves of commercial grade bauxite and to lessen dependence on uncertain overseas aluminum supplies, have investigated in the last 35 years a number of methods for extraction of alumina from high iron bauxite clays and other materials. However, the methods were not competitive at the time with imported alumina and alumina products. It has been predicted that industry by 1980 or shortly afterwards may begin processing low grade domestic bauxites, clays and shales, and other materials such as alunite, anorthosite and leucite containing as little as 30 percent alumina and an important percentage of new aluminum production eventually may be derived from such material.

The North American Coal Corporation produced a high grade aluminum sulfate from coal shales containing 20 to 25 percent alumina as early as 1962-63 and gave serious consideration to a commercial venture to extract alumina from its own refuse piles. Renewed research in this field of coal refuse utilization may be very timely. Particularly since unstable international conditions could make foreign imports unreliable or as the domestic demand increases a cartel may greatly increase the price of the imported alumina; this has happened in the petroleum industry. This subject has not been investigated in detail in the report as it was beyond the scope of study.

Emphasis on Coal Waste Utilization

In performing this study, a great deal of emphasis has been placed on coal waste utilization because it is believed this is one of the areas which offers the most promise for coal operators and others to undertake environmental improvement activities at a profit. What to do with coal waste and how to limit waste in mining and preparation of coal are major issues facing the coal industry today. With coal once again "King," the problem of waste disposal will become even greater as we strive toward energy independence by 1985, if solutions are not found. Utilization of abandoned coal waste deposits and markets for waste from current mining operations will go a long way in solving the coal waste disposal problem.

In 1893, the Commission appointed by the Commonwealth of Pennsylvania to investigate waste from coal mining and methods of utilization stated in the conclusion of their report:

> "They (the Commission) hope that it (the Report) will call the attention of the engineering profession, of the manufacturer, of the producer, and the consumer of coal, and all those interested in the welfare of the State and our great industries, to the lines in which effort should be made to utilize that which, now called waste, is really a storehouse of energy and a source of wealth." p. 54, Reference(23)

It is hoped the emphasis placed on coal waste utilization in this study will be effective in rekindling the objectives so eloquently expressed by the Commission more than 80 years ago.

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REDUCTION OF SURFACE WATER INFILTRATION INTO UNDERGOUND MINES

INTRODUCTION

Surface water infiltration into underground mines through surface mine spoil and fractures caused by subsidence is responsible in some areas for large volumes of acid mine drainage. The reduction of surface water infiltration into active underground mines could reduce acid mine drainage discharges and mine operators may benefit from lower operating costs. The reduction of the unwarranted amounts of water would provide savings to the operator in the way of reduced pumping costs and could extend the life of facilities such as pumps, piping and other equipment exposed to the acid water as well as reducing mine drainage treatment costs.

The filling of surface depressions caused by subsidence of land above underground mines and surface mine reclamation are examples of methods that can be used to reduce surface water percolation. This section of the report is concerned with site improvement costs and projected savings to coal mine operators if methods of reducing surface water percolation are practiced.

PREVIOUS STUDIES FOR WATER INFILTRATION CONTROL

A prefeasibility study completed in 1971 for the Dents Run Watershed, south of Morgantown, West Virginia, indicated the use of water infiltration control methods to eliminate or control acid mine drainage was feasible. The study (1) made for Consolidation Coal Company at their Christopher Coal Division mining operation confirmed the belief that most of the surface mines are hydrologically connected with deep mines and drainage flows from stripped areas into the deep mines. Because the coal seams dip toward the west, water entering the extensive surface mines on the eastern end of the watershed drains toward the active deep mine workings in the western part of the watershed.

It appeared probable that a substantial portion of the discharge from deep mines, as pumped from Christopher Coal Division boreholes, came from diversion of surface water into abandoned mine workings. The two primary methods of mine drainage pollution control recommended were:

1. Control surface drainage to prevent entry into the ground water system. Surface reclamation techniques that backfill the pits covering and sealing the coal seam and exposed entries with grading carried either to natural contours or a swallowtail type of backfill would reduce surface water entry into abandoned mines. The intercepted runoff would be channeled to the normal surface drainage courses in the watershed.

2. Treatment of borehole discharges. Treatment of residual water from boreholes would still be required since not all the drainage entering the coal seams comes from surface mined areas.

The hydrogeological conditions at the study site were presented in the feasibility study(2) conducted in 1971-72. Implementation of surface reclamation techniques to reduce surface water entry into abandoned deep mines would significantly reduce the volume of acid mine drainage. The preliminary flow data indicated a major portion of the total flow in Dents Run is comprised of borehole discharges from active mining operations during normal low flow periods. The Christopher Coal Division's pumping rates are considerably influenced by regional rainfall. An unaccountable loss of stream flow was observed in one segment of Dents Run. It is believed that this water drains back into the Pittsburgh Coal seam through fracture zones or fissures in the stream bed. Stream channelization was recommended for this segment of the stream to prevent infiltration of the water into the groundwater system.

It was recommended that emphasis be placed on surface reclamation techniques in those areas which channel surface runoff into intercepted deep mine workings. It is claimed implementation of the proposed demonstration project will virtually eliminate the high level of acid mine drainage now present. The Christopher Coal Division discharges an average of 3.0 million gallons per day through six boreholes. If this discharge can be considerably reduced the reduction in pumping costs and mine drainage treatment costs should be significant, but no estimate of this reduction is given in the report. The total cost for the infiltration reduction phase of the demonstration project is given as $262,500. The total estimated cost of the project is $687,415 which includes abatement of surface water pollution and monitoring of reclamation work.

COST ANALYSIS OF PERCOLATION REDUCTION TECHNIQUES

The lack of data in the report on borehole pumping costs, mine drainage treatment costs, and the estimated reduction in borehole discharges if surface mines in the eastern part of Dents Run Watershed are reclaimed, makes it difficult, if not impossible, to predict with any degree of accuracy the benefits to the mine operator if water infiltration control techniques are successful. Therefore, an analysis must be made using the indicated values for the project and cost estimate for pumping and mine drainage treatment developed for other studies.

Indicated values for the project are:

1. The cost of the water infiltration control phase of the demonstration project is estimated at $262,500.

2. The average volume of water pumped each day from the six (6) boreholes is 3.0 million gallons.

3. The borehole discharges are moderately to highly acid based on water quality analysis of samples collected over a five month period from August, 1971 to January, 1972 (Table 1).

The Synder Borehole has the largest discharge and it ranged from 0.3 MGD in the dry season to 3.5 MGD in the winter and spring. According to Zavel and Robins(2), this discharge is typically alkaline in nature, but the three water quality analyses in the report indicate that although the pH ranged from 5.6 to 6.1, other water quality parameters were: Total Acidity - 52 to 190 mg/l, Total Iron - 94 to 115 mg/l, and Sulfate - 1538 to 2020 mg/l.

The water quality parameters for the other five borehole discharges were generally in the order of:

pH - 2.4 to 2.9
Total Acidity - 1000 to 4500 mg/l
Total Iron - 300 to 800 mg/l
Sulfate - 3500 to 6000 mg/l

4. Based on topographic maps, the dip of the Pittsburgh Coal seam and sections in Zavel and Robins(2) it is estimated the total length of the six boreholes is about 985 feet. Therefore, the average depth per borehole is about 165 feet.

The cost of percolation reduction techniques should be compared to the cost of collecting and treating water that has entered deep mines through the surface mines. It appears capital and operating costs for collecting water from deep mines are not significant when compared to the cost of mine drainage treatment. Therefore, the real benefit to the coal operator lies in the reduction of mine drainage treatment costs. As water quality standards become more stringent, this cost reduction will become greater. A case in point is EPA's new standards for iron which will necessitate the upgrading or expansion of many mine drainage treatment facilities.

General costs for pumping rate and head can be developed from curves found in the publication "Engineering Economic Study of Mine Drainage Control Techniques." The curves in this publication(3) were updated to June, 1972 using the Engineering News-Record Cost Index and are shown as Figures 1 through 4. The installed costs including boreholes and operating costs for internal pumps (Figures 2 and 4) are applicable for the analysis. The curves are based on data collected on 36 actual pump installations in large mines in southwestern Pennsylvania and northern West Virginia. Drainage pump capacities ranged from 40 gpm (0.06 mgd) to 2500 gpm (3.6 mgd) with a mean of 660 gpm (0.95 mgd). Most of these installations are oversized to allow operation during off peak hours rather than 24 hours a day. The operating cost curves include power costs, maintenance and depreciation. The power consumption for a particular situation may be assumed to be directly proportional to the quantity of water pumped and the head. The power cost is the major cost on a large

TABLE 1

Water Quality Analyses of Christopher Coal Division Borehole Discharges, Dents Run Watershed
Based on Information in Zaveland Robins, 1973(2)

Sample Location Number	Borehole	Sample Parameters	Water Quality Analysis and Date										
			8/16/71	8/30/71	8/31/71	9/20/71	9/21/71	10/19/71	11/15/71	11/16/71	12/7/71	12/15/71	1/14/72
11	**Vallotto**	Flow (gpm)	100		60		35	56	56			--	--
		pH	2.8		3.4		2.9	2.6	2.5			2.8	2.8
		Total Acidity (mg/l)	990		1880		845	1071	1142			702	619
		Total Iron (mg/l)	290		300		250	244	286			240	245
		Sulfate	4280		3720		2900	3299	3259			3100	2800
12	**Hess**	Flow (gpm)	--		90	283		252	281			--	--
		pH	2.7		2.8	2.4		2.5	2.4			2.6	2.5
		Total Acidity (mg/l)	3240		3760	2880		3610	3662			2204	3651
		Total Iron (mg/l)	950		800	980		760	640			620	924
		Sulfate	5240		4560	4560		4996	4625			3690	4364
13	**Loar**	Flow (gpm)	264	335		169		187	187			--	--
		pH	2.9	3.1		2.9		2.5	2.4			2.6	2.5
		Total Acidity (mg/l)	1530	1880		1570		2142	2356			2630	2103
		Total Iron (mg/l)	505	500		500		500	500			590	650
		Sulfate	7610	4800		4510		5057	5058			4830	4367
14	**Snyder**	Flow (gpm)		2800							--		--
		pH		5.8							5.6		6.1
		Total Acidity (mg/l)		52							190		177
		Total Iron (mg/l)		94							100		115
		Sulfate		2020							1765		1538
15	**Six Right**	Flow (gpm)	--	840		--		672	--			--	--
		pH	2.4	2.8		2.6		2.4	2.4			2.4	2.3
		Total Acidity (mg/l)	4230	4420		3850		4428	4900			4600	4505
		Total Iron (mg/l)	900	600		860		720	740			980	930
		Sulfate	5480	4880		6090		6584	6831			6390	5698
16	**Laurel Point**	Flow (gpm)	44	50		50		35		30			
		pH	2.7	3.0		2.7		2.5		2.6			
		Total Acidity (mg/l)	4260	3940		3590		3840		4000			
		Total Iron (mg/l)	1000	920		920		780		760			
		Sulfate	7660	5550		5270		5556		5647			

FIGURE 1
INSTALLED COSTS
EXTERNAL PUMPS INCLUDING BOREHOLES
STAINLESS STEEL

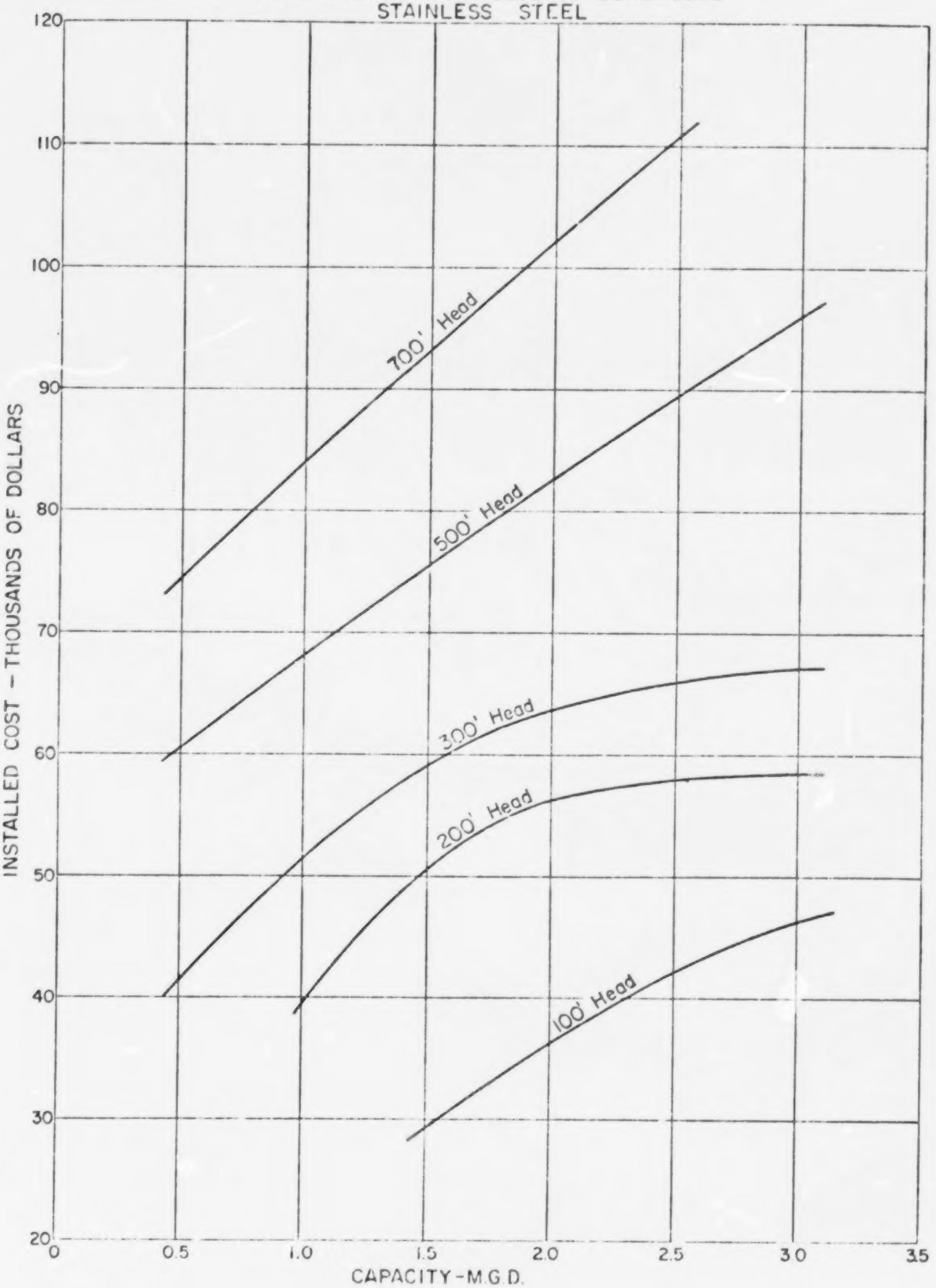


FIGURE 2
INSTALLED COSTS
INTERNAL PUMPS INCLUDING BOREHOLES
STAINLESS STEEL

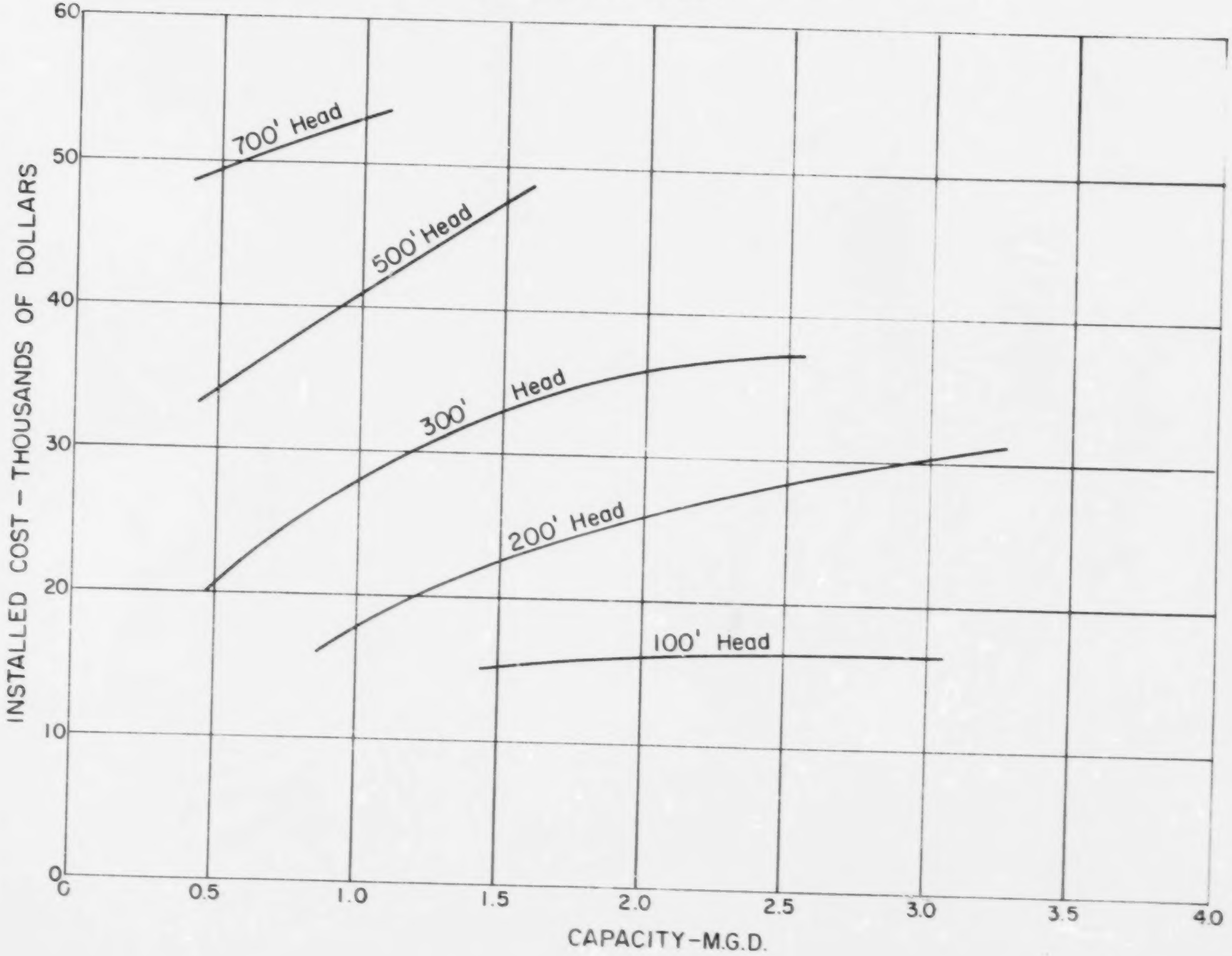


FIGURE 3
OPERATING COSTS
EXTERNAL TYPE PUMPS

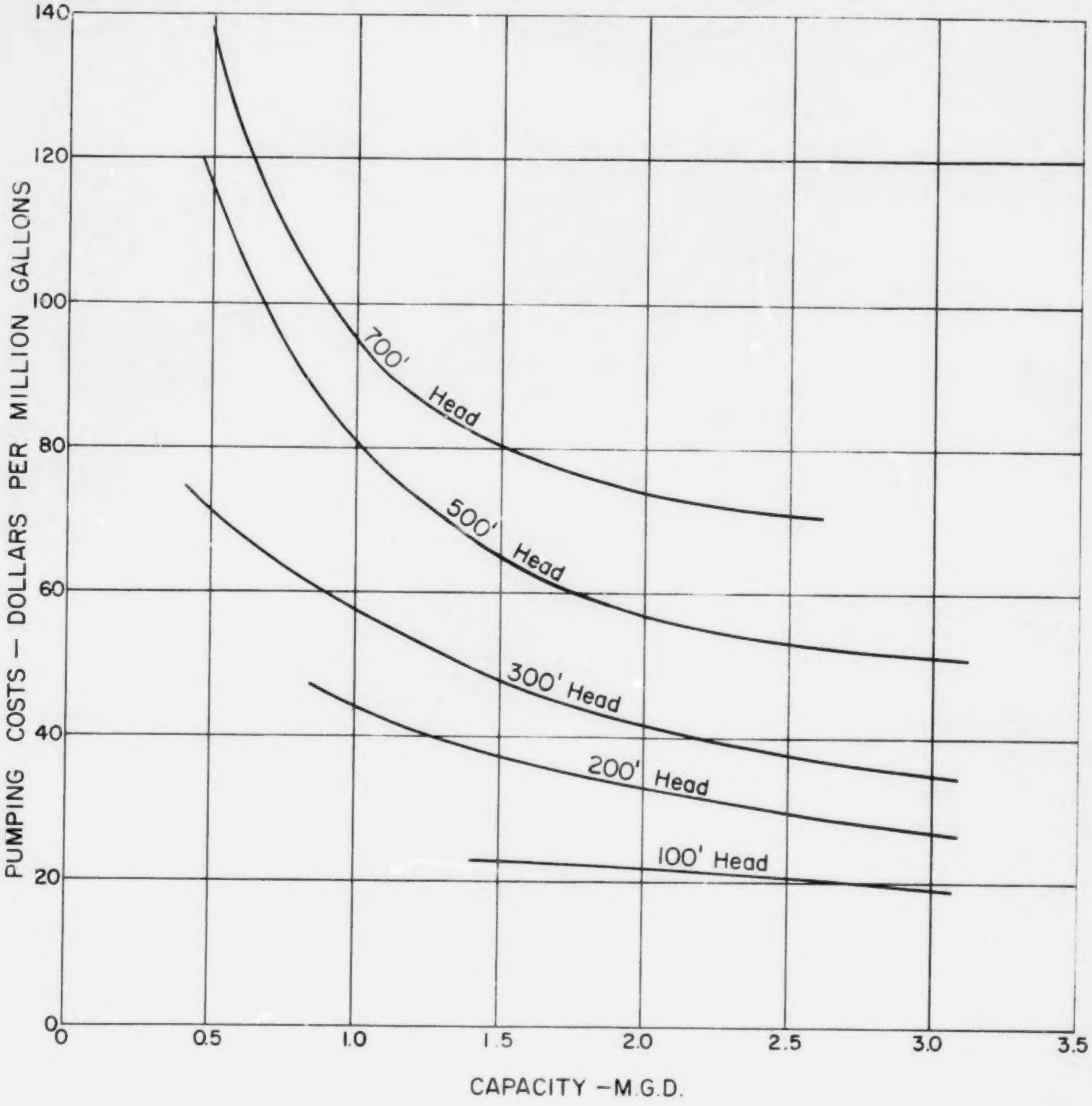
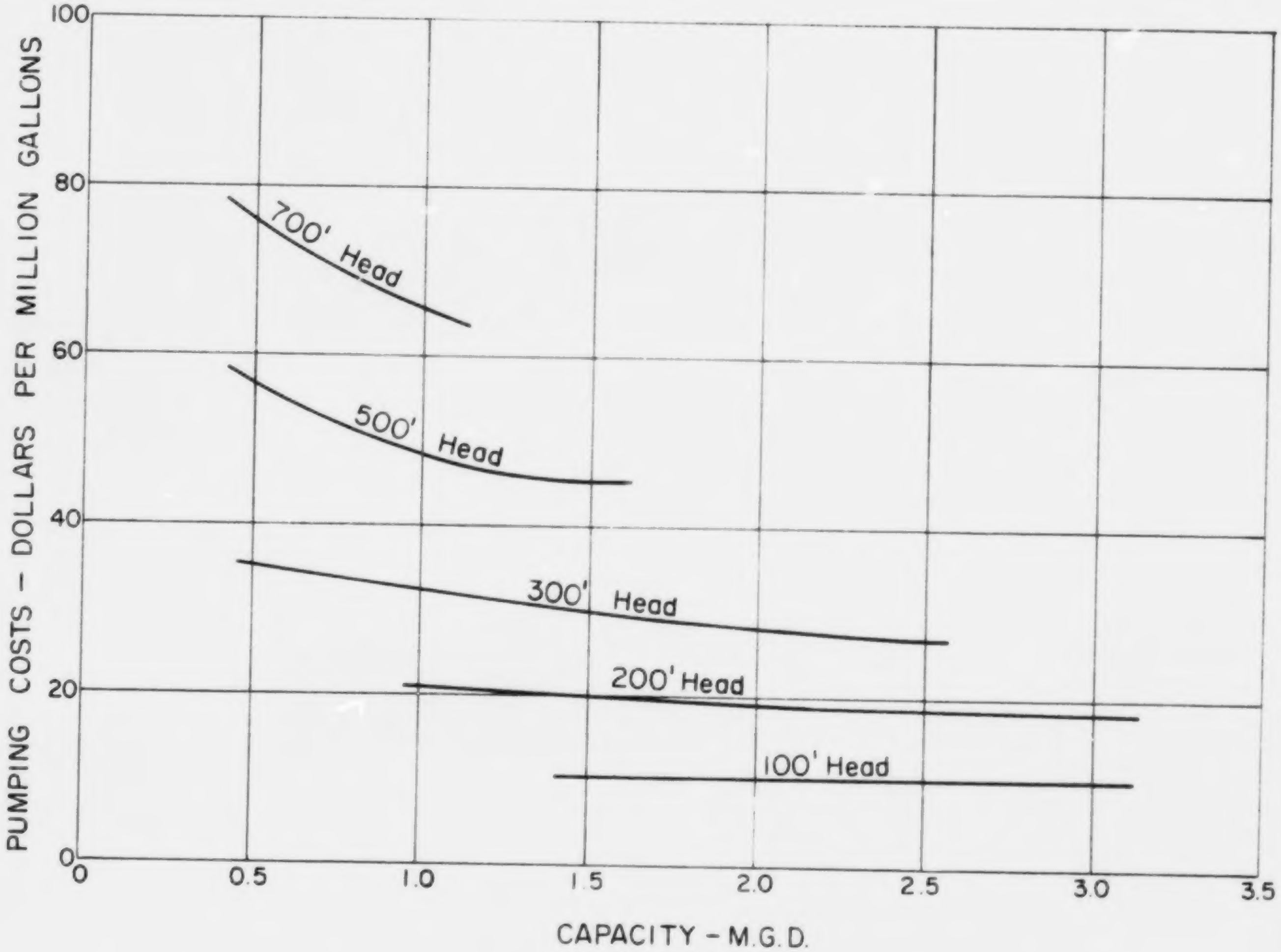


FIGURE 4
OPERATING COSTS
INTERNAL TYPE PUMPS



pump operation. On smaller installations it tends to be overshadowed by depreciation and maintenance, but is still a major item. Anticipated increases in the cost of electrical energy within the next few years will have a considerable effect on power cost, the major component of the operating cost.

The operating costs compare favorably with the cost estimate of $15,000 to $25,000 per year developed by Dr. Parizek(4) for a dewatering system consisting of 3 to 6 wells pumping 2.17 mgd. The cost estimates made by Dr. Parizek were based on analyses presented by Seabar and Hollyday(5) in an unpublished report on the groundwater resources of the Lower Susquehanna River Basin.

The cost of mine drainage treatment is highly variable and reflects the quality and quantity of flow treated, the type of mine drainage treatment installation, land acquisition and site improvement costs, the type and cost of reagent used in treatment, the detention time for treatment of mine waters, the sludge volume, density and disposal method, and other factors.

Dr. Harold Lovell, Head of Mine Drainage Research Section at the Pennsylvania State University indicates that reported figures for treating coal mine drainage tend to underestimate the costs because taxes, depreciation, amortization, maintenance, sludge disposal and other costs are not always included(4). Dr. Lovell indicates that treatment costs may range from $0.05 to $1.25 per 1,000 gallons treated. The lower figure for mine waters containing 2 to 3 mg/l of iron and up to 20 mg/l of acidity, the upper figure is for acid mine water with 500 to 700 mg/l of iron and 2,000 to 5,000 mg/l of acidity. An average figure for treating mine water with 100 mg/l iron and 500 mg/l acidity may be $0.40 per 1,000 gallons using hydrated lime as the reagent.

The study made by Michael Baker, Jr., Inc. for the Appalachian Regional Commission in 1972 titled Analysis of Pollution Control Costs thoroughly discussed mine drainage treatment technology and costs. It was found there was a wide range in treatment costs even when dealing with a similar quality and quantity of flow. Costs ranged from less than a cent to over a dollar per 1,000 gallons treated.

Based on a review of the data on mine drainage treatment in the report Analysis of Pollution Control Costs(6) it appears that a cost of $0.50 per 1,000 gallons treated is not unreasonable for the quality of mine drainage discharged from Christopher Coal Division boreholes in Dents Run Watershed. It should be noted that in the summary of the report a cost of $0.20 per 1,000 gallons treated is recommended for the Monongahela River Basin. This cost estimate is for treating mine drainage from abandoned mines and in many cases mine drainage treatment plants would be located onstream. The cost estimate for mine drainage treatment in Dents Run is for discharge from point sources.

The pumping cost for six boreholes with an average depth of 165 feet discharging 3.0 million gallons each day should be about $42 per day or $15,330 annually (based on a cost of $16 per million gallons pumped - Figure 4). As the discharge is decreased, the pumping cost per million gallons should increase. At 0.5 mgd the pumping cost could be about $20 per million gallons. For an analysis of Dents Run Watershed borehole discharges, an average cost of $18 per million gallons is used regardless of the quantity of water pumped.

Using a cost of $0.50 per 1,000 gallons of mine water treated and $18 per million gallons pumped the annual operating cost to the coal operator for various discharge rates meeting water quality standards should be as presented in Table 2.

TABLE 2

Estimated Annual Operating Cost
Pumping And Mine Drainage Treatment For Various Discharge Rates
Christopher Coal Division Boreholes
Dents Run Watershed, West Virginia

	Discharge Rate in Million Gallons/Day			
	3.0	2.0	1.0	0.5
Pumping Cost	$ 19,710	$ 13,140	$ 6,570	$ 3,285
Mine Drainage Treatment Cost	547,500	365,000	182,500	91,250
Total Annual Operating Cost	$567,210	$378,140	$189,070	$94,535

It is obvious that even if mine drainage treatment costs were only $0.25 per 1,000 gallons treated and the borehole discharges were only reduced from an average of 3.0 to 2.0 million gallons each day, the savings in mine drainage treatment and pumping costs to the coal operator would be enough to amortize the estimated cost of water infiltration control ($262,500) in a period of less than three years.

In the above cost analysis an assumption was made that the water quality of the borehole discharges would not vary greatly as surface water infiltration was controlled. This assumption appears justified based on the limited water quality data (Table 1). Therefore, a uniform cost of $0.50 per 1,000 gallons treated could be used as the discharge rate was decreased.

The quality of infiltrated surface water when it comes in contact with mine waters is a major factor in determining mine drainage treatment cost benefits. If the surface water infiltrating through surface mines, subsidence fractures and abandoned mine workings becomes moderately to highly acid before it reaches the active mining operation, a reduction in the flow would benefit the coal mine operator. A large reduction in surface water infiltration under these conditions would result in a substantial savings in mine drainage treatment costs. The cost in $/1,000 gallons treated for the underground water in the active mine after surface water infiltration is controlled will depend on the quality of the underground water without the addition of surface water infiltration. If the underground water contained less iron and acidity, the unit cost in $/1,000 gallons treated would be lower for the decreased discharge.

On the other hand, when the underground mine water is highly acid and the surface water entering the mine is alkaline or contains little iron and acidity, the quality of the underground mine water is improved by mixing of the two waters. Under these conditions, the unit cost in $/1,000 gallons treated will increase as surface water infiltration is controlled and the mine water discharge becomes more concentrated with mineral acidity. The overall reduction in mine drainage treatment costs may not be significant and they may be negligible.

Before a site can be considered a candidate for percolation reduction, a thorough study should be made of water quality factors to determine if surface water infiltration control will bring about a reduction in mine drainage treatment costs. It appears the saving in water collection cost alone is not enough of an economic incentive to justify the cost of surface reclamation.

The capital cost projection for a mine drainage treatment facility may be the economic incentive in cases where a decrease in mine drainage treatment cost does not justify the cost of water infiltration control. The volume of water to be treated to a certain extent influences the sizing of treatment plant components such as holding lagoons, aeration lagoons, sludge settling and concentration lagoons, piping, tanks and other equipment. Land acquisition and site improvement costs should also be greater for a treatment facility handling a larger volume of mine water.

Table 3 presents annual mine drainage treatment costs for various discharge rates and unit cost in $/1,000 gallons treated. The cost in $/1,000 gallons treated may increase in many cases as surface water infiltration control becomes effective, but the increase in unit cost probably will not be large enough to offset the benefits resulting from the reduction in discharge. Two probable reasons for an increased unit cost are:

1. The reduction in surface water infiltration may expose previously flooded portions of the mine to pyrite oxidation, thereby increasing mineral acidity of the mine water.

2. The surface water percolating into the underground mine may have had a dilution effect on the underground mine water.

Two hypothetical examples indicating the estimated operating cost benefit that may accrue as surface water infiltration is decreased are presented in Tables 4 and 5. In both examples the unit cost increases as the discharge decreases. The unit costs for mine drainage treatment in $/1,000 gallons treated are:

	Table 4	Table 5
3.0 MGD	$0.20	$0.30
2.0 MGD	0.30	0.40
1.0 MGD	0.40	0.50
0.5 MGD	0.50	0.60

The pumping cost is based on a 300 foot head. Using Figure 4, the cost per million gallons pumped for the discharge rates are:

3.0 MGD	$26
2.0 MGD	28
1.0 MGD	32
0.5 MGD	35

In both examples a sizable reduction in discharge must occur before there is a substantial benefit to the mine operator. In Table 4 when there is a reduction of 1.0 MGD in discharge, the only benefit to the operator is a decrease in pumping cost of about $8,000 annually. In this case it would not be feasible for a coal operator to invest in a surface water infiltration control project if the discharge cannot be reduced to about 1.5 MGD.

There is a limited amount of information available on water infiltration control to prevent mine drainage pollution from active mines. Physical approaches to the problem of preventing water entry into coal mines, as a means to broaden water improvement techniques beyond removal and treatment, have only recently been undertaken(7). In the past mine management has been concerned with removing water from active mining sections primarily because it hampered the movement of mining equipment and aggravated the working condition of the miners. Therefore, it is difficult to estimate the benefits to coal operators using this approach because little is known about the water quality relationship between the infiltrating surface water and the underground mine water. The water quality improvement and cost benefit will depend on many factors unique to a particular mine situation. But it appears the cost benefit to the operator should be significant when discharges are moderately to highly acid and unit costs for mine drainage treatment of the total discharge before water infiltration control are $0.40 per 1,000 gallons treated or greater.

TABLE 3

Annual Mine Drainage Treatment Costs
Discharge Rate and Cost in $/1,000 Gallons Treated

Cost $/1,000 Gallons Treated	Discharge Rate in MGD			
	3.0	2.0	1.0	0.5
$0.20	$ 219,000	$146,000	$ 73,000	$ 36,500
0.30	328,500	219,000	109,500	54,750
0.40	438,000	292,000	146,000	73,000
0.50	547,500	365,000	182,500	91,250
0.60	657,000	438,000	219,000	109,500
0.70	766,500	511,000	255,500	127,750
0.80	876,000	584,000	292,000	146,000
0.90	985,500	657,000	328,500	164,250
1.00	1,095,000	730,000	365,000	182,500
1.10	1,204,500	803,000	401,500	200,750
1.20	1,314,000	876,000	438,000	219,000

TABLE 4

Estimated Annual Operating Cost
Pumping And Mine Drainage Treatment For Various Discharge Rates

	Discharge Rate in MGD			
	3.0	2.0	1.0	0.5
Pumping Cost	$ 28,470	$ 20,440	$ 11,680	$ 6,387
Mine Drainage Treatment Cost	219,000	219,000	146,000	91,250
Total Annual Operating Cost	$247,470	$239,440	$157,680	$97,637

TABLE 5

Estimated Annual Operating Cost
Pumping and Mine Drainage Treatment For Various Discharge Rates

	Discharge Rate in MGD			
	3.0	2.0	1.0	0.5
Pumping Cost	$ 28,470	$ 20,440	$ 11,680	$ 6,387
Mine Drainage Treatment Cost	328,500	292,000	182,500	109,500
Total Annual Operating Cost	$356,970	$312,440	$194,180	$115,887

ACTIVE MINES IN THE MONONGAHELA RIVER BASIN HAVING A HIGH POTENTIAL FOR PERCOLATION REDUCTION

To determine the most suitable sites for surface water infiltration control projects, approximately 300 deep mines in the Monongahela River Basin were reviewed using information developed by the Environmental Protection Agency(8,9) and other sources. The use of two simple criteria reduced the number of sites having a possible high potential for percolation reduction to 22. The criteria were:

1. The site had to be an active mine because the objective of the study was to identify sites where a coal operator could profitably undertake pollution reduction activities. An economic incentive for private industry to perform a pollution reduction project would help lessen the crushing pollution abatement cost to the government in the Mononghela River Basin.

2. In order for a possible economic incentive to be present, it was felt that the mine discharge must produce at least 100 lbs. per day of acid and/or iron. This rough guideline was developed out of necessity. There is no doubt that the volume of mine discharge is also an important factor, but it has been pointed out that water collection costs alone do not appear to be enough of an economic incentive. A large discharge producing only 100 lbs. per day of acid probably could be treated economically and the cost may be a few cents per 1,000 gallons treated, whereas, a small discharge producing 100 lbs. per day of acid would have a higher unit cost for treatment.

Two of the mine sites were eliminated because they were already candidates for percolation reduction studies. Table 6 is a tabulation of data on the 20 mines proposed for investigation of percolation reduction studies. Based on the review of information developed by others, a study of topographic maps, available mine maps, and limited information in reports and publications, only a few of the sites appear to offer a really attractive economic incentive for surface water infiltration control. The following is short discussion of each of the selected sites:

1. Jones and Laughlin Steel Corp.
   Vesta No. 4 Mine

   This is a shaft and drift mine located under Pike Run in Washington County, Pennsylvania. The discharge is alkaline, but the iron concentration exceeds water quality standards. The mine lies near the crest of the Belle Vernon anticline. Several small streams flow above the mined area and several areas adjacent to the deep mine have been strip mined. There are also several abandoned drift mines in the area. Courses of action include strip mine reclamation, stream diversion, and selective lining of stream channels where surface water percolates into the deep mine through fracture zones or fissures in the stream bed.

TABLE 6
MONONGAHELA RIVER BASIN
MINES PROPOSED FOR INVESTIGATION OF PERCOLATION REDUCTION STUDIES

Company and Mine	Sub-Basin	Location	Type	EPA Inventory No.
Jones and Laughlin Steel Corp. Vesta No. 4 Mine	Lower Monongahela, Pennsylvania	Under Pike Run in Washington County, Pa.	Shaft and Drift	5 - 029
Bethlehem Steel Corp. Ellsworth No. 51 Mine	Lower Monongahela, Pennsylvania	Ellsworth, Pa.	Shaft	12 - 005
Mathies Coal Co. Mathies Mine	Lower Monongahela, Pennsylvania	Under Mingo Creek in Washington County, Pa.	Shaft and Drift	25 - 044
Jones and Laughlin Steel Corp. Gateway Mine	Tenmile Creek, Pennsylvania	Between Ruff Creek and N. Fork of Tenmile Creek, Pa.	Shaft	21 - 061
Republic Steel Corp. Clyde No. 3 Mine	Tenmile Creek, Pennsylvania	S.E. of Marianna, Pa.	Shaft	21 - 064
Jones and Laughlin Steel Corp. Shannopin Mine	Dunkard Creek Pennsylvania	Area around and N.W. of Shannopin, Pa.	Shaft and Drift	44 - 070
United States Steel Corp. Robena Mines	Middle Monongahela, Pennsylvania	Under Whitely Creek near Masontown, Pa.	Shaft and Slope	21 - 101
Duquesne Light Co. Warwick No. 2 Mine	Middle Monongahela, Pennsylvania	1 to 2 miles N.W. of Greensboro, Pa.	Drift and Shaft	20 - 119
National Mines Corp. Crucible and Isabella Mines	Middle Monongahela, Pennsylvania	Area around Crucible and Isabella, Pa. and south to Carmichaels, Pa.	Shaft	20 - 352
Christopher Coal Co. Humphry No. 7 Mine	Dunkard Creek, Pennsylvania and West Virginia	N.W. and S.E. of Mount Morris, Pa.	Shaft and Drift	44 - 055

TABLE 6 (CONTINUED)
MONONGAHELA RIVER BASIN
MINES PROPOSED FOR INVESTIGATION OF PERCOLATION REDUCTION STUDIES

Company and Mine	Sub-Basin	Location	Type	EPA Inventory No.
Christopher Coal Co. Pursglove No. 15 Mine	Upper Monongahela, West Virginia	Between Scotts Run and Robinsons Run-NW of Morgantown, W. Va.	Shaft and Drift	44 - 042
Mountaineer Coal Co. Consol No. 20 Mine	Lower West Fork, West Virginia	Four States, W. Va. and W. to Stringtown, W. Va.	Shaft	54 - 195
Mountaineer Coal Co. Williams Mine	Lower West Fork, West Virginia	N.W. of Enterprise near Wyatt, W. Va.	Shaft	54 - 186
Clinchfield Coal Co. Compass No. 3 Mine	Ten Mile Creek, West Virginia	Dala, W. Va. on Little Ten Mile Creek	Drift and Shaft	61 - 003
Clinchfield Coal Co. Compass No. 2 Mine	Ten Mile Creek, West Virginia	S.E. of Dala, W. Va. on Little Ten Mile Creek	Drift	64 - 133
Galloway Land Co. Dawson Mine	Lower West Fork, West Virginia	S. of Lumberport, W. Va. to Crooked Run	Drift	64 - 095
Mountaineer Coal Co. No. 93 Mine	Upper Monongahela, West Virginia	Area N. of Rivesville, West Virginia	Shaft and Drift	28 - 009
Republic Steel Corp. Banning No. 4 Mine	Lower Youghiogheny, Pennsylvania	Area 3.5 miles E. of Donora, Pa.	Shaft	11 - 032
Consolidation Coal Co. Hutchison Mine	Sewickley Creek, Pennsylvania	Hutchison, Pa.	Shaft	9 - 001
Delmont Fuel Co. No. 10B Mine	Sewickley Creek, Pennsylvania	3.8 miles S.E. of Hutchinson, Pa.	Drift	9 - 077

2. Bethlehem Steel Corp.
Ellsworth No. 51 Mine

The shaft mine is located west of Jones and Laughlin's Vesta No. 4 near the trough of the Pigeon Creek syncline. The limited surface mining has been restricted to the overlying Redstone coal seam. Several streams flow over the mined area. The mine discharge which is treated produces a large amount of acid and iron. Reclamation would include lining of stream channels and surface mine reclamation.

3. Mathies Coal Co.
Mathies Mine

This is a combination shaft and drift mine under Mingo Creek in Washington County, Pennsylvania. Streams flow above the mined area. Only a limited amount of surface mining has taken place. Percolation reduction at this mine would include stream diversion and selective lining of stream channels in those places fractures and fissures allow infiltration of stream flow into the deep mine.

4. Jones and Laughlin Steel Corp.
Gateway Mine

The mine is located on Ten Mile Creek, north of Jefferson, Pennsylvania. This shaft mine produces a large discharge which is alkaline, but iron concentration exceeds water quality standards. Studies should be performed to determine if mine subsidence is responsible for the large volume of water occurring in the deep mine.

5. Republic Steel Corp.
Clyde No. 3 Mine

This is a shaft and drift mine located southeast of Mariana, Pennsylvania. The large discharge is alkaline, but iron concentration greatly exceeds water quality standards. A number of streams flow above the mined area. Recommended measures for percolation reduction include stream diversion, selective lining of streams and filling of subsidence areas.

6. Jones and Laughlin Steel Corp.
Shannopin Mine

The Shannopin Mine is located in the area around and northwest of Shannopin, Pennsylvania. It is a combination drift and shaft mine with drifts in the eastern part and shafts in the west. A generalized structural geology map indicates the mine lies on the westward dipping limb of the Fayette anticline. The stream channel of Dunkard Creek is above the mine workings. Only limited surface mining has occurred in the area. It appears some reduction in surface water infiltration is possible if surface mines to the east are reclaimed. The selective lining of stream channels where surface water percolates through fractures and fissures in the stream bed may be effective in reducing the large discharges from the mine. There are two large discharges, each over 500 gpm; one is moderately acid, the other alkaline with a low iron concentration.

7. United States Steel Corp.
   Robena Mines

This is a shaft and slope operation located under Whiteley Creek near Masontown, Pennsylvania. Overlying the Robena Mines are a number of flowing streams. There are also a number of abandoned drift mines in the area. The mines are located on the westward dipping limb of the Fayette anticline. In this area the Pittsburgh coal seam has not been stripped west of the Monongahela River. Coal seams down to and including the Pittsburgh have been extensively stripped east of the Monongahela River. Surface water infiltration control would include surface mine reclamation, stream diversion, lining of stream channels, and sealing of abandoned mines.

8. Duquesne Light Company
   Warwick No. 2 Mine

The combination drift and shaft mine is located one to two miles northwest of Greensboro, Pennsylvania in the vicinity of Whiteley Creek. The mine is situated on the western limb of the Fayette anticline. Overlying the mine are a few small strip mines. The large discharges from the mine, 1,200 to 1,500 gpm, are treated. Surface water percolation reduction would include strip mine reclamation, lining of stream channels, filling of subsidence areas and stream diversion. Coal refuse from nearby piles could be used in reclamation.

9. National Mines Corp.
   Crucible and Isabella Mines

This shaft mine complex is located in the area around Crucible and Isabella, Pennsylvania and south to Carmichaels, Pennsylvania. The mines discharge a large volume of alkaline water. Iron concentrations exceed water quality standards in two of the three largest discharges, 15 to 120 mg/l of iron. The mines extend under the Monongahela River at several points and a number of smaller streams flow over the mined area. The selective lining of stream channels, filling of subsidence depressions and possibly stream diversion are methods to reduce the exceptionally large discharges.

10. Christopher Coal Company
Humphry No. 7 Mine

The combination shaft and drift mine is located northwest and southeast of Mount Morris, Pennsylvania. Mine discharges are alkaline and iron concentrations are low. A number of small streams flow above the mined area and there are abandoned drift mines and a few strip mines. Possible reclamation measures are surface mine reclamation, stream diversion and sealing of abandoned mines.

11. Christopher Coal Company
Pursglove No. 15 Mine

This shaft and drift mine is located between Scotts Run and Robinsons Run and is northwest of Morgantown, West Virginia. The mine is situated on the westward dipping limb of the Fayette anticline. There are a number of unreclaimed surface mines and coal refuse piles in the area. Water quality data was not available at the time of the EPA survey because the mine was closed down due to a fire. If surface water infiltration is responsible for large discharges, suggested courses of action would include surface mine reclamation, stream diversion, selective lining of stream channels, and filling of subsidence depressions.

12. Mountaineer Coal Company
Consol No. 20 Mine

The shaft mine is located approximately eight miles west of Fairmont, West Virginia. There are no strip mines above the mined area and only a few streams cross the area. The discharge was about 50 gpm at the time it was sampled by EPA. The net acidity was 174 lbs. per day and iron was 144 lbs. per day. There is a possibility that lining of stream channels where fractures allow percolation of surface water into the mine and filling of subsidence depressions may further reduce the discharge.

13. Mountaineer Coal Company
Williams Mine

The shaft mine is northwest of Enterprise near Wyatt, West Virginia. There are a number of strip mines, abandoned drift mines and water courses above the mined area. The mine is situated near the trough of the Shinnston syncline. Highly acid discharges are being treated. Reclamation of strip mines, filling of subsidence depressions and selective lining of stream channels may be effective in reducing the acid discharges.

14. Clinchfield Coal Company
Compass No. 3 Mine

The shaft and drift mine is located at Dola, West Virginia on Little Ten Mile Creek north of the Compass No. 2 Mine. The mine is situated on the westward dipping limb of the Wolf Summit anticline. Surface mines in the vicinity appear to be sources of surface water percolation into the deep mine. Streams flowing above the mined area may contribute surface water infiltration through fractures in the stream bed resulting from subsidence. Possible remedial measures to reduce the acid discharges would include surface mine reclamation, diversion ditches and selective lining of stream channels.

15. Clinchfield Coal Company
Compass No. 2 Mine

This drift mine is also situated on the westward dipping limb of the Wolf Summit anticline but it is located southeast of Dola, West Virginia on Little Ten Mile Creek. Possible reclamation measures include surface mine reclamation, diversion of drainage from drift openings and selective lining of stream channels. This mine has been cited as an area where a stream is diverted directly into underground workings.

16. Galloway Land Company
Dawson Mine

The mine is located northwest of Clarksburg, West Virginia in the vicinity of Crooked Run and Lambert Run. Extensive strip mining has taken place above the mined area. This particular site appears to be one of the most favorable for percolation reduction techniques through reclamation of surface mines.

17. Mountaineer Coal Company
No. 93 Mine

This combination shaft and drift mine located north of Rivesville, West Virginia has at least three large discharges of highly acid water. Data from the field inventory performed by EPA indicates that three of the acid flows have a total discharge of about 600 gpm, a net acid load of over 20,000 lbs. per day, and an iron load of about 6,000 lbs. per day. The mine is situated on the westward dipping limb of the Fayette anticline. Streams flow above the mined area and there are a few strip mines. The large discharges indicate surface subsidence may be a factor in surface water percolation. Because of the exceptionally high acid and iron load, this site appears to be suited for percolation reduction techniques.

18. Republic Steel Corp.
Banning No. 4 Mine

The shaft mine is located in an area 3.5 miles east of Donora, Pennsylvania. The mine is situated on the eastward dipping limb of the Belle Vernon anticline. The highly acid discharge is nearly 2,000 gpm and the net acid and iron load per day are over 26,000 lbs. and 7,500 lbs. respectively based on EPA's field inventory data. The discharges are being treated by the mine operator. Water infiltration problems appear to be enormous as the Youghiogheny River flows above the mined area. This site would have to be thoroughly investigated before a decision could be made as to the benefits of water infiltration control.

19. Consolidation Coal Company
Hutchinson Mine

The shaft mine is located northeast of West Newton, Pennsylvania with the main shaft opening at Hutchinson. The mine is situated in the trough of the Irwin syncline, and consequently, the water in abandoned mines up dip flows into the active workings. According to EPA, the mine contributes 46 percent of the total pollution from the Sewickley Creek sub-basin. The field inventory data indicates the flow is about 5,000 gpm, net acidity over 40,000 lbs. per day and iron above 15,000 lbs. per day. This mine has the greatest need for drainage control within the Monongahela River Basin. Water percolating into strip mines east of the Hutchinson mine appear to enter the active operations. Subsidence areas above active and abandoned operations also contribute surface water infiltration. The water infiltration problems associated with this mine are very complicated and a thorough study would have to be made to determine the feasibility of water infiltration control techniques.

20. Delmont Fuel Company
No. 10B Mine

This is a drift mine located approximately 3.8 miles southeast of Yukon, Pennsylvania. It lies down dip from a few small strip mines. The acid discharge is about 200 gpm and part of this flow may be derived from water percolating into the surface mines.

ACTIVE MINE SITES STUDIED FOR POSSIBLE INITIATION OF WATER INFILTRATION CONTROL TECHNIQUES

As part of the study, the Appalachian Regional Commission selected three active mine sites for further investigation. A study was to be performed to determine if acid mine drainage control programs could be initiated to reduce surface water percolation into these underground mines. Only two mines were investigated because the third mine selected was closed during the entire study period. The man hours for investigation of the third mine site were utilized by increasing the level of effort in collection of field data on coal mine refuse. The two mines studied were the Marianna No. 58 of Bethlehem Steel Corporation and the Shannopin Mine of Jones and Laughlin Steel Corporation. The mine operators cooperated in every way and supplied available information.

Bethlehem Steel Corporation Marianna No. 58 Mine

The Marianna No. 58, a deep shaft mine located in Washington County, Pennsylvania, was investigated in August, 1972. It is the oldest active underground mine in Pennsylvania and was opened during the early 1900's. The Pittsburgh coal seam is mined and the mine workings now cover an area of about 12 square miles. The mine is within the trough of a gently dipping syncline.

The room and pillar method of mining is practiced and during retreat from each section or panel, the pillars are extracted allowing the roof to cave. Except for main haulageways, ventilation passageways and active sections, all pillars have been robbed. Mine floor elevations range from 395 to 540 feet above sea level. The overburden thickness varies from a minimum of 400 feet to a maximum of 1,100 feet. According to Bethlehem mining engineers there is no surface expression of subsidence.

Worked out areas of other mines are to the north, east and south. A solid block of coal remains only to the west where active mining is now in progress. At a current extraction rate of approximately 1,200,000 tons per year, the coal reserve will be exhausted in about 80 years. It is possible that the Marianna No. 58 shaft may be abandoned in the future because of increasing haulage distances to the hoisting shaft. In this event a shaft would be sunk to the west. A barrier pillar would be left to isolate the abandoned worked out area.

The Marianna No. 58 is a relatively dry mine and the total discharge is usually used up in the preparation plant which also neutralizes acid water in case an excess flow occurs. Apparently vertical percolation rates are low due to shale and clay aquitards which limit surface water infiltration. The overburden rock appears to be competent and not readily subject to fracturing. The sources of water entering the active mining operations are:

1. The abandoned flooded portion of the Republic Steel Corporation Clyde Mine to the east. This appears to be the largest source of water infiltration. The Clyde Mine is structurally higher and the impounded water behind the barrier pillar which separates the two mines seeps through fractures. Percolation reduction would require at least 9,600 feet of grout curtain to seal fractures.

2. The Shidler air shaft located in an abandoned section of Marianna No. 58. The air shaft provides some ventilation of active operations and sealing the shaft would effect mine ventilation.

3. The least significant source of water are sedimentary dikes of clay or claystone which are occasionally encountered as the face is advanced. The flow from the dikes are of short duration.

At present, the mine water is being collected with four pumps at a cost of about $60,000 per year and is being used in the preparation plant where the discharge is neutralized.

There is no economic incentive for water infiltration control at this mine. Water collection costs are small compared to the cost of percolation reduction techniques such as grouting the barrier pillar separting the Clyde and Marianna No. 58 mines.

In addition to evaluating the Marianna No. 58 Mine as a possible candidate for water infiltration control techniques, a brief study was made of the mechanism whereby the highly acid mine drainage is neutralized when it is used to clean coal in the preparation plant. Samples of the coal being processed, the acid water pumped from the deep mine and the water recirculated in the coal washing process were collected and analyzed. The water quality analyses are presented in Table 7. The analyses are typical of the quality of water pumped from the mine and the coal preparation plant discharge.

The Marianna No. 58 Mine is unusual in that coal washing is performed with highly acid mine drainage which is neutralized during the cleaning operation. It appears fracture fillings of secondary calcite present along cleavage surfaces in the coal and within a binder bed are mainly responsible for neutralization of the acid water.

Research conducted by Pennsylvania State University(10) has shown that calcium carbonate in coal will react with sulfuric acid in mine drainage to increase pH, decrease acidity and remove iron. Some neutralization may also be attributed to soluble alkalies. The acidity and iron can be reduced to negligible concentrations.

The response of sulfuric acid in coal mine drainage to coal is dependent upon coal composition, processing history and particle size. It also varies with the nature of the mine drainage, coal to water ratio and reaction time. The Penn State study indicated the significant coal composition characteristic was the calcium carbonate content and the most critical variable affecting the rate and therefore the amount of acidity removed per unit of time was coal particle size. The neutralizing ability of coal increased as reaction time and concentration of coal in the mine drainage was increased. Once coals were subjected to wet preparation processes they were found to be essentially non-reactive. This lack of chemical activity is related to the prior reaction during coal preparation.

The factors which are significant in neutralization of acid mine drainage at the preparation plant of the Marianna No. 58 mining operation are:

1. The coal and binder layer contain fracture fillings of secondary calcite and the coal tends to break along these fractures exposing the calcite to acid water.

TABLE 7

Water Quality Analyses - August 2, 1972
Bethlehem Steel Corporation Mariana No. 58 Mine

	Water Pumped from Mine	Preparation Plant Water Returned from Settling Pond
pH	2.80	8.35
Hot Total "P" Acidity (equiv. mg/l $CaCO_3$)	3470.	-17.
Total "P" Acidity (equiv. mg/l $CaCO_3$)	3020.	-2.
Free Acidity (equiv. mg/l $CaCO_3$ at pH 4.5)	1100.	0.
Total Alkalinity (equiv. mg/l $CaCO_3$)	0.	55.
Total Hardness (equiv. mg/l $CaCO_3$)	3050.	1450.
Calcium Hardness (equiv. mg/l $CaCO_3$)	820.	980.
Magnesium Hardness (equiv. mg/l $CaCO_3$)	2230.	470.
Total Iron (mg/l)	610.	0.18
Total Filterable Iron (mg/l)	510.	---
Ferrous Iron (mg/l)	225.	---
Aluminum (mg/l)	430.	0.02
Manganese (mg/l)	80.	5.8
Calcium (mg/l)	330.	390.
Magnesium (mg/l)	540.	140.
Sodium (mg/l)	2080.	980.
Sulfate (mg/l $SO_4^{=}$)	8350.	2600.
Chloride (mg/l Cl^-)	2030.	820.
Fluoride (mg/l F^-)	---	2.

2. The volume of water pumped from the mine to the preparation plant is not large compared to the quantity of coal undergoing the wet preparation process.

3. The mine water is highly acid and has a low pH which favors reaction of sulfuric acid with calcite.

4. The mine drainage is aerated at several steps of the water collection and coal preparation process including the mine, holding pond, jigging tables, settling and aeration tanks and settling pond. The aeration effectively converts ferrous iron to ferric iron and promotes reaction with the calcite.

5. The water used in coal preparation is recirculated. Therefore it comes in contact with more coal containing calcite fracture fillings and also receives further aeration.

6. A certain percentage of the powdered limestone used in rock dusting probably ends up in the preparation plant along with the coal and aids in neutralization.

7. The lower concentrations of hardness, magnesium and sodium in the water returned from the settling pond indicate dilution by surface water. The surface water is probably alkaline because limestones are present in the area.

8. Recirculation of preparation plant water increases the calcium ion concentration. This benefits water quality because the solubility product of calcium sulfate is exceeded and crystalline calcium sulfate is precipitated in the aeration and settling tanks. The result is a reduction in sulfate concentration of the effluent.

Neutralization of acid mine drainage at the Marianna No. 58 Mine has been very effective because there is only a small highly acid discharge being pumped from the mine and it is needed in operation of the preparation plant where the water is recirculated to insure an adequate supply for coal processing. Complete neutralization occurs because the mine water is aerated at several stages of the preparation process and the total weight of sulfuric acid in the mine water is less than the equivalent weight of calcium carbonate as calcite fillings in coal fractures and limestone rock dust.

Coal preparation plants using wet processes and acid make-up water can expect an improved quality discharge water depending upon water recirculation, total coal-water contact time and the calcium carbonate content of the coal being processed. A high pH cannot be obtained unless there is adequate aeration.

The physical and chemical conditions at the Mariana No. 58 Mine may also exist at other mines in the Monongahela River Basin. Further study of this pollution abatement phenomenon appears warranted. Physical and chemical conditions under which coal may contain fracture fillings of calcite are:

1. The coal mined is in the Monongahela and Conemaugh Groups of Pennsylvanian Age. Limestones and dolomite are more prevalent in these groups.

2. Gentle folding of rock strata has developed the fractures necessary for the occurrance of calcite deposition. Coal mines at or near the crest of an anticline or the trough of a syncline may be favorable for this condition.

3. The ground water is saturated with respect to calcium carbonate, and

4. The coal is mined at a depth below major drainage elevations.

Jones and Laughlin Steel Corporation Shannopin Mine

The Shannopin, a shaft and drift mine located in Greene County, Pennsylvania, was investigated in September, 1972. The Pittsburgh coal seam is mined and has a minable thickness of about six feet. The mine was developed on the flank of a syncline and the rock strata dips to the northwest approximately 100 feet per mile. Figure 5 is a mine map of the Shannopin showing drifts, shafts, worked out areas, adjacent deep mines and structure contours drawn on the base of the Pittsburgh coal seam. The extent of strip mining and the location of drift mine entries in the Waynesburg, Sewickley and Pittsburgh coal seams are presented on Figure 6. Figure 7 is the legend for Figures 5 and 6.

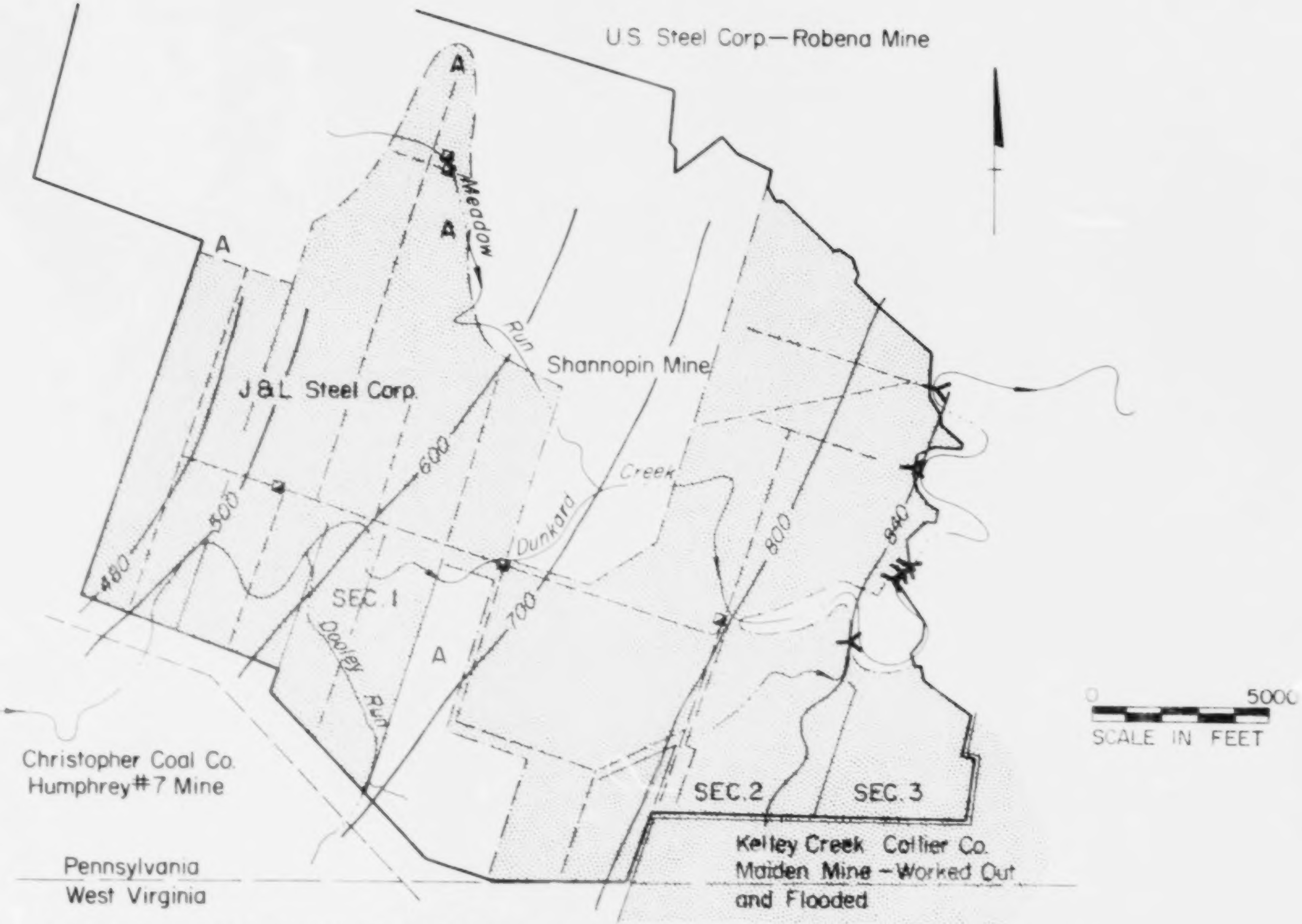
Two areas of the Shannopin Mine have water percolation problems. One area, designated as Section 1 on the mine maps underlies Dooley Run which at the time of the investigation had no flow. The other area where a large flow of water enters the mine is at the southeast corner of the Shannopin Mine limit adjacent to the flooded Maiden Mine and is designated as Sections 2 and 3. There is a minimum of overburden in the second area.

Section 1 - Dooley Run Drainage Basin

About seven or eight years ago retreat mining resulted in surface subsidence and fracturing of rock strata within the Dooley Run drainage basin. The stream flow was lost at this time. An overburden thickness of 350 feet was not sufficient to prevent subsidence and fracturing of rock strata underlying the drainage basin.

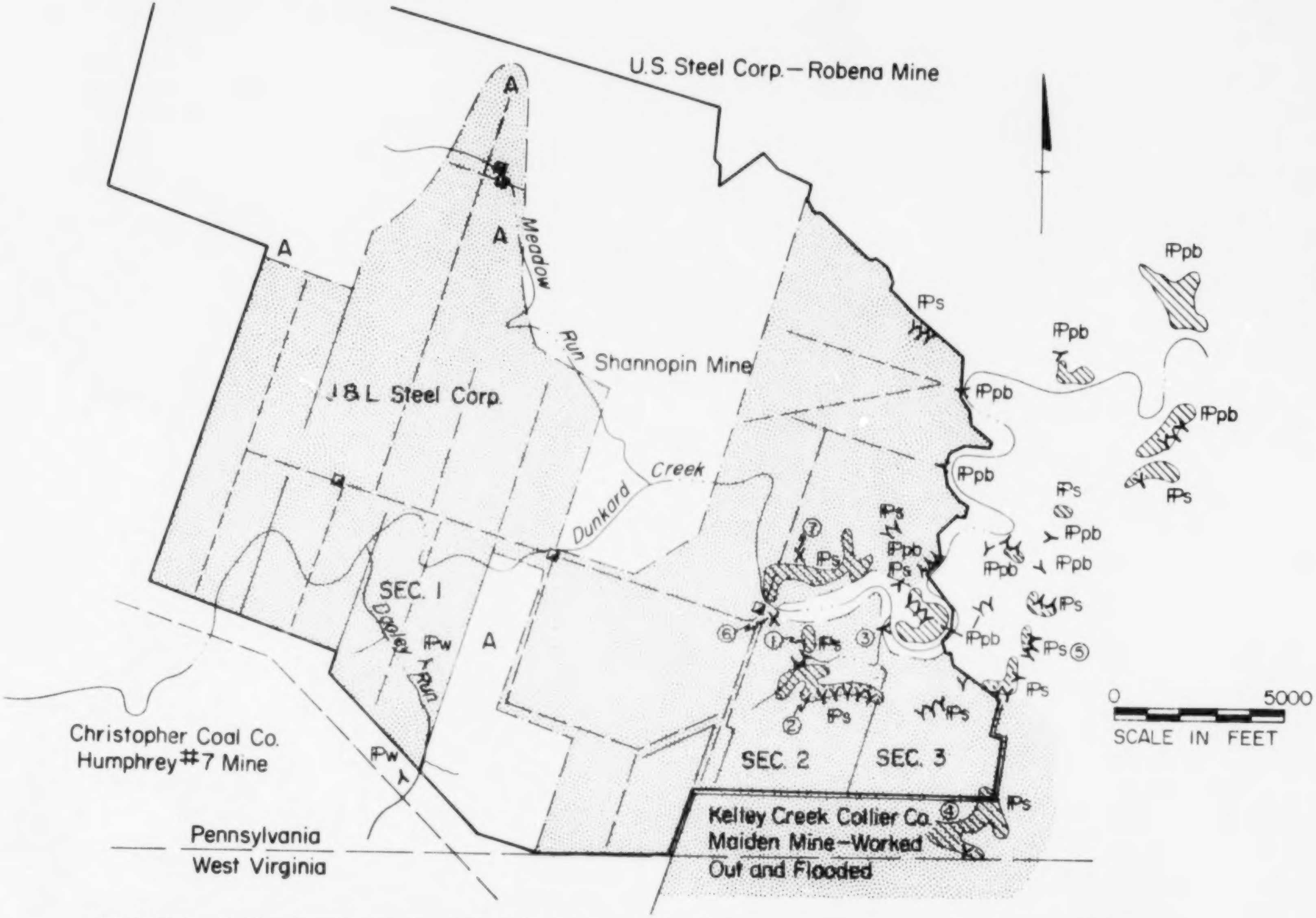
When this section of the Shannopin Mine was designed and laid out care was taken to minimize acid production. The Jones and Laughlin Steel Corporation obtained the services of the late Dr. S. A. Braley, a preeminent authority on acid mine drainage formation and abatement who was doing research at the Mellon Institute. With his assistance, the following practices were adopted(11, 12):

Figure 5


U.S. Steel Corp.—Robena Mine
A
Meadow
A
A
Run
Shannopin Mine
J&L Steel Corp.
600
Creek
Dunkard
500
480
SEC. 1
Dooley
Run
A
700
800
840
0
5000
SCALE IN FEET
Christopher Coal Co.
Humphrey #7 Mine
SEC. 2
SEC. 3
Kelley Creek Collier Co.
Maiden Mine—Worked Out
and Flooded
Pennsylvania
West Virginia

MAP OF SHANNOPIN MINE SHOWING DRIFTS, SHAFTS AND STRUCTURE CONTOURS

Figure 6


U.S. Steel Corp.—Robena Mine
Shannopin Mine
J & L Steel Corp.
Meadow Run
Dunkard Creek
Dooley Run
SEC. 1
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Christopher Coal Co.
Humphrey #7 Mine
Kelley Creek Collier Co.
Maiden Mine—Worked Out and Flooded
Pennsylvania
West Virginia
0
5000
SCALE IN FEET

MAP OF SHANNOPIN MINE SHOWING ADJACENT DRIFT MINES AND STRIP MINES

Figure 7

LEGEND FOR FIGURES 5 & 6

Maps of Shannopin Mine

———	*Limit of Shannopin Mine*
— — —	*Limit of Worked Out Areas*
▭	*Worked Out Areas*
- - - -	*Main Haulageways*
— 500 —	*Structure Contours Drawn on Base of Pittsburgh Coal Seam*
■	*Shaft*
≺	*Drift Mine Opening*
A	*Areas Where Mining of the Pittsburgh Seam is Active*
▨	*Strip Mine*
₱w	*Waynesburg Coal Seam*
₱s	*Sewickley Coal Seam*
₱pb	*Pittsburgh Coal Seam*
~	*Stream*

1. Surface water and ground water were diverted where practical to prevent the entry of, or reduce the flow of, water into and through the mine workings.

2. Water was not allowed to accumulate in working areas. Sumps were dug in low spots and kept pumped out, thereby keeping water from acid forming pyrites on the face. Numerous pickups were employed for each pump.

3. Wherever possible, pipes instead of ditches were provided to conduct water by gravity. This kept exposure to acid forming material on the bottom to a minimum.

4. Gathering or main sumps were provided in the mine by driving separate sump entries or by digging up the bottom. This practice did not permit water to accumulate in the local low gob areas with large acid producing surface areas exposed to the water. The large sumps also provided reservoir capacity and prevented surges of mine water entering the stream.

5. Discharges into streams were regulated, insofar as practical, to equalize daily accumulation throughout a 24-hour period.

This adherence to good drainage practice, which generally followed recommendations of the Ohio River Valley Sanitation Committee(13) demonstrated that, in some circumstances, mine drainage pollution can be eliminated by proper planning and mine design. The drainage analysis(12) of water pumped to the surface from the Shannopin No. 3 Air Shaft is as follows:

	Average	Range
pH	7.2	6.8 - 7.8
Fe (mg/l)	1.0	0 - 5.5
Flow (GPD)	100,000 (Approx. 70 GPM)	

The average flow pumped from this section of the mine is about 100,000 gallons per day, but a wide variation in flow exists depending upon precipitation and runoff in the Dooley Run drainage basin. The EPA field inventory data indicates that at the time they sampled this discharge the flow was 500 gallons per minute which would be 720,000 gallons per day if the flow remained constant for 24 hours. The EPA water quality parameters for this discharge are:

pH	7.2
Net Acidity (mg/l)	- 835
Net Acidity (lbs./day)	-5023
Iron (mg/l)	4.1
Iron (lbs./day)	25

A field investigation performed on September 14, 1972 revealed Dooley Run had no flow near its confluence with Dunkard Creek. Other streams in the area were at high flow and a flash flood watch was in effect. Dooley Run drainage basin is about 1,135 acres. It would be reasonable to expect the stream to have a flow of at least 1.0 cfs on this day. A flow of 1.0 cfs is more than 600,000 gallons per day.

A few days later, Dooley Run was examined for its entire length. Wet areas were noted in the headwaters and a brook near the headwaters had a small flow. Dooley Run also had a small flow in the headwaters area which gradually disappeared approximately 1,200 feet downstream of the brook. Below this point the stream bed was dry.

Local residents indicated after retreat mining large cracks developed in the stream bed in the vicinity of a drift mine opened for the Waynesburg coal about 4,000 feet upstream from Dunkard Creek and a gas line serving the residents was ruptured. The fissures are no longer visible.

It is concluded from field evidence that essentially all precipitation within the drainage basin less that lost through evapotranspiration is percolating into the mine through subsidence fractures and fissures. This is an example of where mine subsidence has caused the capture of most of the precipitation that falls within the drainage basin.

Infiltration of water into this section of the mine from other sources is ruled out because:

1. The section of the Marianna No. 58 Mine to the west is not flooded and a barrier pillar 50 to 100 feet thick separates the two sections. Also the dip of the strata is to the northwest which would cause water to flow away from Section 1.

2. Infiltration from the Humphrey No. 7 Mine of the Christopher Coal Division of Consolidation Coal Company is unlikely because the mine is active and the barrier pillar separating the two mines has a thickness of 1,000 feet which should effectively prevent infiltration.

The problem of reducing surface water infiltration in the Dooley Run drainage basin is complicated by the fact that bedrock exposures indicate the rocks are predominantly jointed sandstones. It appears water infiltration is widespread and occurs throughout the drainage basin and not just at places where subsidence caused major fracturing of the overburden. Because of the extensive subsidence, fracturing and jointing in the overburden it is concluded that percolation reduction techniques such as lining stream channels or stream diversion would not be effective.

Sections 2 and 3 - Adjacent to Maiden Mine

The most serious mine drainage pollution problem in the Shannopin mine complex is in the southeastern part of the mine. The highly acid mine drainage is collected and pumped to the surface at the No. 1 Air Shaft Borehole. The discharge is then pumped to a holding lagoon, from which it flows by gravity to a neutralizing tank. The neutralizing agent is quicklime which is slaked with water in a separate slaker unit.

The mine drainage has an extremely high ferrous iron content and aeration is required to form a stable ferric iron precipitate. Aeration prior to neutralization is not effective because the iron will not oxidize readily in an acid medium. After neutralization, sufficient aeration is obtained as the water flows through an open trough and down the bank to a settling lagoon. Retention time in the settling lagoon is a minimum of 24 hours.

The volume of sludge produced is about 40,000 gallons per day and permanent lagoons are used for storage. The capacity of the settling lagoons is about 10 million cubic feet.

The volume of water being treated has increased because of diversion of acid water from several other locations in the Shannopin Mine including some of the mine drainage from the No. 3 Air Shaft Area. The roof caving following retreat mining in Section 1 below Dooley Run has led to the formation of acid water in some parts of the section.

Although the mine drainage treatment flow scheme is relatively simple, the sheer magnitude of the flow and its high mineral content have made operation of this installation a major job. The lime requirement is 5 to 6 tons per day and the pH control has to be manual because of the long holding time in the lagoon. Automatic recording and control of pH was not successful because of excessive gypsum deposition on the probes. Deposition of gypsum from the treated water has been the source of several operating problems. Most of these problems have been overcome by 1) mounting the pump on a float, with provisions to lift it from the water and drain it when not in use, 2) vertical lifts are pumped through flexible hosing, which can be cleared of gypsum deposits by rapping on the hose, and 3) the underground pipes orginally installed to transfer water from the upper to the lower lagoon were replaced with open flumes, which can be cleared with a shovel when needed(12).

The holding lagoon has proven beneficial in several ways. It levels off the acid surges being pumped from various areas of the mine. This makes treatment by the lime slaker easier and makes it possible to control by varying the amount of acid water in the feed rather than the amount of lime from the slaker, which would be difficult, due to the elapsed time required to slake lime, or by installation of a complicated variable volume pump to feed milk of lime(12).

The volume of discharge and the water quality before and after treatment for the years 1968 and 1970 at the Shannopin No. 1 Air Shaft Borehole and treatment facility are[12]:

	1968		1970	
	Feed	Effluent	Feed	Effluent
pH	2.5	7.8	2.9	7.5
Fe (mg/l)	700	2.5	350	1.0
Flow (GPD)	700,000		1,000,000	

The EPA field inventory data indicates that at the time they sampled the borehole discharge the flow was 521 gallons per minute which would be about 750,000 gallons per day if the flow remained constant for 24 hours. The EPA water quality parameters for the discharge are:

pH	4.0
Net Acidity (mg/l)	1186
Net Acidity (lbs./day)	7428
Iron (mg/l)	243
Iron (lbs./day)	1522

An investigation was made of the area above and adjacent to the southeast part of the Shannopin Mine in September, 1972. This area is designated as Sections 2 and 3 and Figure 6 presents the mining features of the area. They are:

1. An abandoned strip mine in the Sewickley coal seam which has been regraded.
2. An active strip mine and drift mines in the Sewickley coal seam.
3. A sealed drift mine in the Pittsburgh coal seam which connected with the Shannopin Mine. The mine entry is above drainage.
4. A reclaimed strip mine in the Sewickley coal seam.
5. Abandoned strip mines and drift mines in the Sewickley coal seam. One of the drift mine headings is partially flooded.
6. Site of the Shannopin No. 1 Air Shaft, borehole and pump station.
7. Site of the Shannopin No. 1 Air Shaft Borehole mine drainage treament facility.

Streams were found to be flowing and there did not appear to be any water loss in the stream bed of Dunkard Creek. The numerous abandoned drift mines in the stratigraphically higher Sewickley coal seam were dry except for one heading which was partially flooded with stagnant water. The strip mines are also in the Sewickley coal seam and it is doubtful if water percolates to the Shannopin Mine from these sources.

Most of the water entering Sections 2 and 3 must originate in the flooded Maiden Mine to the south. The percolation is through the barrier pillar which separates the Shannopin Mine from the flooded worked out section of the Maiden Mine. Percolation reduction techniques would require sealing the barrier pillar between the two mines and this does not appear to be practical. The cost of infiltration reduction control would be prohibitive compared to present operating costs and the life expectancy of the mining operation.

SURFACE WATER INFILTRATION CONTROL RESEARCH

The formation, quantity and characteristics of coal mine drainage is dependent upon the geology, hydrology, mineralogy and climatology of the originating area and the alteration of the prevailing conditions by a deep mining operation. This localized environment establishes the conditions which control the chemical reactions that introduce soluble components into any waters in the system(14). The ideal solution is to collect or divert ground water before it reaches the mine environment.

A variety of techniques for preventing surface water from entering the mine environment were reviewed by Lorenz in 1962(15). Several studies have been performed in recent years by Pennsylvania State University(4, 14, 16) and others(17, 18) to identify and describe relationships which control water infiltration into the mine environment. These studies are concerned with interpretation of the relationship between geological, hydrological, chemical and mining method parameters which could control existing and prevent future deleterious mine drainage conditions. The evaluation of various practical methods to prevent ground water infiltration, such as well dewatering and types of well dewatering to be employed are discussed.

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THE CONCURRENT RECLAMATION OF PARTIALLY WORKED OUT DEEP AND/OR SURFACE MINES AND THE RECOVERY OF COAL RESERVES

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THE CONCURRENT RECLAMATION OF PARTIALLY WORKED OUT DEEP AND/OR SURFACE MINES AND THE RECOVERY OF COAL RESERVES

INTRODUCTION

As part of Operation Scarlift, Pennsylvania's 500 million dollar bond issue for a Land and Water Conservation and Reclamation Fund, recovery of coal from areas previously deep mined has been initiated in reclamation programs. The purpose of this approach is to more effectively reduce acid mine drainage by stripping areas where mine sealing is not practical. In some areas the strip mining reduces the length of the clay seal needed to effectively isolate the remaining deep mined area. The recovery of coal is secondary, although it can decrease the cost of required excavation.

So far two projects have been completed and a third project is in progress. The completed projects are the Shaw Mine Complex (SL 118-2 and SL 118-2A) in Somerset County and a drift mine near Burgettstown (SL 130-3) in Washington County. An extensive underground mine complex in the Little Toby Creek Watershed in Elk County is the site of the third project.

CASE STUDIES OF THE THREE PROJECTS

Shaw Mine Complex (SL 118-2 and SL 118-2A)

The Shaw Mine in Somerset County is in an area that has been extensively mined for the Pittsburgh coal seam by both underground and surface methods. The mine complex covering about 35,000 acres is the largest source of acid mine drainage in the Casselman River, a tributary of the Youghiogheny River.

As the M. F. Fetterolf Coal Company was stripping for coal nearby, the Pennsylvania Department of Environmental Resources negotiated contracts with the company on a rental of equipment basis for strip mining a portion of the deep mine. The purpose of the work was to hydrologically isolate part of the mine. After the stripping operation was completed, a clay barrier seal was constructed to flood a portion of the mine.

Strip mining resulted in a highwall height of a little over one hundred feet. It is estimated that if all the coal was in place, profitable strip mining would have limited the highwall height to 60 or 70 feet. The coal recovery amounted to 10 to 20 percent of the original reserve. The low recovery can be attributed to a high initial recovery during the underground mining operation and the subsequent crushing and mixing of materials as a result of subsidence. Only the larger pillars and stumps were recoverable.

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A total of 16,176 tons of coal were recovered during the strip mine operation and the Pennsylvania Department of Environmental Resources claimed a credit of $2.50 to $3.00 for each ton of coal recovered. The project cost figures are as follows:

Contract SL 118-2

Invoice for Total Construction Cost	$318,705
Less Coal Credit (7,482.3 tons @ $2.50/ton)	-18,705
Net Invoice	$300,000

Contract SL 118-2A

Invoice for Total Construction Cost	$723,918.75
Less Coal Credit (8,693.75 tons @ $3.00/ton)	-26,081.25
Net Invoice	$697,837.50

The total credit for the coal recovered on this project was $44,786. Although the Shaw Mine Complex has been only partially reclaimed, a noticeable reduction in pollution has occurred as a result of the strip mining and installation of clay barrier seals. Additional strip mining and clay barrier sealing will be performed in the future under Contract SL 118-2B also awarded to the M. F. Fetterolf Coal Company and other contracts for reclamation are proposed for this area. The later contracts will not be on a rental of equipment basis but will be awarded on a lump sum basis.

Deep Mine Near Burgettstown, Pennsylvania (SL 130-3)

The Bologna Coal Company, under contract to the Pennsylvania Department of Environmental Resources, strip mined a portion of a drift mine in the Raccoon Creek Watershed near Burgettstown in Washington County. The Company was working a strip operation nearby and the contract was negotiated on a rental of equipment basis for a cost not to exceed $300,000.

The work was performed to eliminate a source of acid mine drainage seeping into a residential area. After the strip mining operation was completed, a clay seal was constructed along the exposed deep mine workings and the area then backfilled with spoil.

The deep mine was stripped to a highwall height of about 70 feet where unfractured overburden was encountered. Mining was in the Pittsburgh coal seam and approximately 70 percent of the coal had been recovered by deep mining methods. It is significant to note the previously unmined top or rooster coal was recovered in addition to the remaining Pittsburgh coal. It is doubtful if the rooster coal could be sold today because of its very high sulfur content.

The Pennsylvania Department of Environmental Resources was credited $3.00/ton for the coal recovered and the project cost figures are as follows:

Invoice for Total Construction Cost	$367,000
Less Coal Credit (39,700 tons @ $3.00/ton)	-119,400
Net Invoice	$247,600

The credit for the coal recovered resulted in a project cost reduction of 32.5 percent indicating the benefits that can occur from this type of reclamation program.

Deep Mine in Little Toby Creek Watershed

The Pennsylvania Department of Environmental Resources had originally intended to strip mine a portion of an extensive deep mine complex in the Little Toby Creek Watershed in Elk County so that they could more effectively reduce acid mine drainage discharges by constructing a hydraulic clay seal barrier along the highwall. However, the landowner refused to grant permission and subsequently made an agreement with the Ivan Starr Coal Company to make an additional pass along the highwall of the active strip mine operation over the deep mine workings. The Department discussed the proposed pollution abatement program with the coal company and they are agreeable to following the wishes of the Department wherever possible. Apparently the Starr Coal Company believes sufficient coal remains to make the additional pass profitable.

After the strip mining is complete, the Department of Environmental Resources will let contracts for construction of hydraulic seals and other abatement work in the area.

LEGAL AND POLICY MATTERS

Because the strip mine operation and recovery of coal is considered by the Pennsylvania Department of Environmental Resources to be a part of the overall reclamation plan of an area, the Department is in a position to offer economic and other incentives to operators. The requirements obligating the mining company to obtain mining permits, drainage permits and other permits can be waived. The posting of a bond is not required.

PHYSICAL SITUATIONS INFLUENCING CONSIDERATION OF THIS RECLAMATION PROCEDURE

Deep Mine Areas

1. The deep mine is a source of acid mine drainage pollution which cannot be readily abated by construction of mine seals. Examples would be mines with numerous openings and those that have been mined too close to the outcrop.

2. Sufficient coal should remain in place for secondary coal recovery to be an incentive. Concurrent coal recovery is not an incentive where pillars have been robbed over an extensive area or subsidence has caused a crushing and mixing of materials.

3. The overburden should not be too thick. If the highwall height is great, intervening coal seams of good quality must be present. An intervening seam containing one to two feet of good quality coal could reduce reclamation costs.

4. In areas of high water infiltration caused by subsidence, strip mining may be the only practical alternative even when coal recovery will be minimal.

5. Concurrent coal recovery and reclamation should be applied to areas where construction of seals at openings and curtain grouting are not practical because of the following physical situations: a) the mine has numerous openings and fractures, b) extensive subsidence has occurred fracturing the overburden, c) previous strip mining has intercepted deep mine workings and a clay barrier seal along the highwall is necessary, and d) the overburden is not thick and the coal remaining in place can be recovered.

Auger Mining Along Highwall of Strip Mine

1. Pollution from the augered portion of the mine cannot be readily abated with clay seals.

2. Auger mining is usually associated with thin coal seams, although seams five to seven feet thick have been mined by this method. It is doubtful that coal recovery would be significant in stripping an auger mined area.

Strip Mines Without Deep Or Auger Mining Beyond the Highwall

1. Generally, the prospects of reducing acid mine drainage discharges by recovering the coal beyond the highwall can be considered poor.

2. Although the area beyond the highwall may contribute acid discharges because of the disturbance of strata and a lowering of the water table, strip mining to recover coal may actually increase the volume of acid discharges in spite of burial of toxic material and proper backfilling.

RECOMMENDATIONS AND CONCLUSIONS

The case studies indicate concurrent reclamation of partially worked out deep and/or surface mines and the recovery of coal reserves was initiated because acid mine drainage could be more effectively abated by construction of a clay barrier hydraulic seal along the highwall created by strip mining a deep mined area. The construction of individual seals at mine openings and curtain grouting probably would not have been as effective in reducing acid discharges because of the numerous openings and/or extensive subsidence with associated fracturing of strata.

In areas that had been partially stripped, additional strip mining was performed to: 1) extend the strip mine to an area of relatively unfractured overburden above the deep mine, thereby reducing or eliminating high rates of water infiltration into the deep mine workings, and 2) shorten the length of the required clay barrier hydraulic seal.

The recovery of coal was of secondary importance. The primary objective was to more effectively reduce acid mine drainage discharges. The initiation of a concurrent coal recovery - reclamation project will depend on several factors and each site must be evaluated on an individual basis. Factors to be considered are:

1. The physical parameters including thickness of overburden, number of mine openings and the degree of fracturing and subsidence of the overburden.

2. The cost of strip mining less credit for coal recovery including cost of clay barrier seal and soil treatment and planting vs. cost of individual mine seals and curtain grouting.

3. The anticipated reduction in acid mine drainage for each reclamation method analyzed.

4. The legal and jurisdictional framework.

5. The land use after reclamation.

It is possible land use may justify a higher reclamation cost. A subsidence prone area that is a source of acid mine drainage in or near a urbanized area could be strip mined and graded for use as an industrial or residential development. In addition to a coal recovery credit which may be nominal the increased value of the reclaimed land should be considered an economic incentive.

The concurrent reclamation of partially worked out deep and/or surface mines and the recovery of coal reserves is placed in another perspective if a regional or watershed approach to reclamation is considered. Although several mine drainage treatment projects have been designed to treat the effluent of an entire watershed, most reclamation projects to date have been concerned with reduction of acid mine drainage from a particular source or several sources within a watershed. Studies have been made on a watershed basis, but the interrelationship between reclamation, coal recovery, land use and other factors have not been considered in the overall studies.

If environmental, mineral resource, economic and political factors of a watershed are considered as a whole, a reclamation procedure which does not appear attractive as an entity may be very attractive in the overall development plan for the watershed.

The complexity of pollution abatement in an extensively mined watershed is well illustrated in the mine maps presented in Investigative Mine Survey of a Small Watershed(2). The report prepared by Halliburton Company for the Environmental Protection Agency is an intensive investigation of the Browns Creek coal field, West Virginia. Hundreds of mine openings within the watershed would require sealing and many of them are buried beneath backfills of stripped areas. Some of the deep mine openings are drifts or crosscuts exposed lengthwise by strip mining and present very difficult sealing problems. Extensive subsidence has also occurred throughout the watershed.

Many mined watersheds similar to Browns Creek exist in Appalachia. This report is recommended for a better understanding of the complexity of the pollution abatement problem when dealing with extensively mined watersheds. The plans and mine maps indicate any reclamation program considering environmental factors only will be very costly and of doubtful value. Potential benefits could occur if coal recovery, water supply, future development within the watershed and other basin needs are considered.

Although the Browns Creek Watershed is used as an example in the following discussion of an approach that can be taken in reclaiming an extensively mined watershed, it should be pointed out that no study has been made of the economics of secondary coal recovery, future land use requirements and other basin needs as they apply to Browns Creek and the vicinity of Clarksburg, West Virginia.

Browns Creek is one of the major tributaries of the West Fork River. The average acid load for the West Fork at Clarksburg, West Virginia is about 5,500 lbs./day and Browns Creek contributes about 25 percent of the acid load (1,350 lbs./day). The average daily iron and sulfate load contributed by Browns Creek into the West Fork River constitutes 81 percent and 23 percent respectively.

The Browns Creek Watershed is about 6.8 square miles in area and located 2.5 miles south of Clarksburg, the fifth largest city in West Virginia and seat of Harrison County. Clarksburg is the major center of population and industry in the Upper West Fork River Sub-Basin. The West Fork River is utilized by Clarksburg for its potable water supply. Increasing water treatment costs for treating total hardness and removing minerals have occurred because of contamination of the river by acid mine drainage. Browns Creek has been cited by the Clarksburg Water Board as being so badly polluted for the past 40 years that it cannot be used for any purpose.

The extensive deep, strip and auger mining in the Browns Creek coal field has been in the Pittsburgh seam and to some extent in the Redstone seam. The Pittsburgh coal seam ranges in thickness from 5 to 9 feet. The Redstone is not generally present in a commercially mineable thickness, however, it is sometimes found in seams as thick as 2 feet. In many areas within the watershed the thickness of overburden above the Pittsburgh seam is less than 100 feet although it reaches a thickness of 300 feet at the summits of hills.

The Appalachian Region in general and northern West Virginia in particular, has limited gently rolling to level land suitable for large scale development or farming beyond the subsistance level. Clarksburg, as the fifth largest city in West Virginia does have the potential for growth. A growing city needs an adequate water supply, a first class airport, areas for industrial development along its perimeter, waste disposal sites and possibly nearby recreational areas.

A watershed approach to reclamation in Browns Creek could consider the recovery of coal and the potential long term needs of Clarksburg. The reclamation plan would be to develop broad, level areas suitable for future development. The use of large scale surface mining equipment with inherent lower earth moving costs would be justified. Entire hilltops could be stripped, the coal recovered, and the spoil used as fill in low lying areas. The terrace-like stripped areas would be more stable than the usual steep, contour slopes developed in strip mining for coal in Appalachia. Several areas appear ideal for construction of an airport.

A changing land use concept would also be part of the long range reclamation and coal recovery plan. At first, land that is not needed for immediate use in industrial or other development, could be used as pasture land. As a soil profile developed, grazing land would be used for a higher use such as truck farming. Clarksburg, with modern sewage facilities, could supply activated sludge to serve as fertilizer for the agricultural economy. Spray irrigation of sewage effluent as developed by Pennsylvania State University and as instituted by St. Charles, Maryland in their unique sewage disposal system could also be practiced.

A project of this type could be feasible, but it is doubtful the private sector could ever undertake a project of such tremendous scope because of the requirements of long range planning, initial capital and operating costs, the difficulty in acquiring surface and mineral rights from many property owners, and the long period of time before a profit would be realized. The profit potential reported by Dr. Erkan Esmer(3) of West Virginia Institute of Technology for reclaiming and developing land in mountain top removal strip mining makes the possibility of a daylighting project of this type very attractive.

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THE PROSPECTS OF RECLAMATION AND REVEGETATION OF MINED LANDS FOR PROFITABLE TIMBERING AND/OR PULPWOOD INDUSTRY

Secondary land usage, in this case reforestation of mined lands for the timber and pulpwood industries, is of particular value because of the integral part it plays in the total reclamation process. The land is not dormant but is actively renewing a resource, timber. In the end, the success or failure of this type of project will depend upon its economic feasibility. Revegetation projects in West Virginia have costs ranging from $90.00 to $287.00 per acre for a mixed grass-tree vegetation type. Revegetation costs in Pennsylvania were substantially higher, ranging from $247.00 to $500.00 per acre for a mixed grass-tree vegetation type(1). These costs are for reclamation performed to prevent or limit mine drainage and sedimentation and not with the end view of forest products utilization.

The initial costs of reforestation will be increased by additional forest management costs. Fire prevention, road construction, and taxes add to the cost of the initial investment. Fire prevention costs average $0.80 per acre per year, road construction costs average $800.00 per mile with additional maintenance costs when necessary, and land tax costs average $0.35 per acre per year(2). The high initial investment and yearly costs coupled with the length of time prior to marketability of the product make annual incomes minimal, if existant at all. Profit realization will not occur until the harvestation begins. However, with proper management, large economic returns can be realized annually after approximately 20 years, depending upon the type of forest(2).

Successful reforestation is dependent upon several physical and chemical properties of the soil(3). The amount of alteration of these properties necessary before planting can begin will affect the cost of the project. Texture, the most important physical property, influences the amount of water available for plant growth. Spoils with high clay contents compact easily, restricting the quantity of water percolating through the surface cover and entering the zone of aeration. Spoils composed of a high percentage of coarse-grained materials allow rapid infiltration. However, these materials are subject to periods of drought because of their high transmissibilities, the rate at which water moves through the soil(4). The texture and degree of compaction determine the drainage characteristics of the spoil.

Chemical properties of importance are acidity, total soluble salts, organic matter, and the soil nutrient level. Soil pH, a measure of acidity, controls the solubility and availability to plants of many nutrients. Generally, as pH values fall below 4.5 more toxic ions go into solution and fewer nutrients are available to the plants. A high concentration of total dissolved solids may interfere with seed germination or plant growth and development. Organic matter serves as a source of nutrients. The absence of organic matter will, in most cases, necessitate the application of fertilizer prior to planting. Similiarly, the soil nutrient levels will indicate the quantities and types of fertilizer required for successful plant growth(3).

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The primary objective of revegetation of mined land is erosion control and reduction of mine drainage discharges. It is, therefore, necessary to establish a ground cover as rapidly as possible. Among others, bermudagrass and tall fescue have experienced large scale usage in Appalachia in reclamation of mined land. Recently, weeping lovegrass has experienced a great popularity. The reasons for this popularity are: (1) it can survive in a wide-range of soil acidities, pH values as low as 4.0 to 4.5, (2) it is short-lived and dies out after 2 or 3 years, (3) it provides a quick cover, and (4) it is not competitive with other species(5). This lack of competitiveness has resulted in the successful direct seeding of black locust and weeping lovegrass. At this time, black locust is the only hardwood reported to have been direct seeded successfully, while no softwoods have been reported.

In Appalachia, there is a need for both hardwood and softwood timber for the pulpwood industry(2). The needs of a specific location must be examined prior to the implementation of any reforestation project.

Direct seeding is the easiest and least expensive method of planting a mixed grass-tree cover. As stated previously, direct seeding of black locust (Robinia pseudoacacia) and weeping lovegrass (Eragrostis curvula) to reduce erosion has been successful(5). After one growing season, 24 black locust survived on 0.02 acre. Extrapolation of the data to one acre indicates a potential growth of 1,200 trees, approximately double the number used in reforestation. Black locust trees when planted with weeping lovegrass have a high survival rate. Also, black locust trees are beneficial in that they: (1) are useable by the pulpwood industry, (2) establish a canopy rapidly, and (3) provide nitrogen to the soil. Several other hardwoods - hybrid poplar, European alder, green and white ash, and cottonwood, adapted successfully to an acid environment. However, the limited data available indicate only black locust can successfully compete with grasses using the direct seeding method. Use of seedlings increases the planting cost because of the labor required in hand-planting. Also, competition with grasses could necessitate a waiting period of several years for grasses to lose their initial vigor and allow survival of trees.

Planting seedlings of black locust, European alder (Alnus glutinosa), and hybrid poplar (P. mayimowiczii) without a grass cover on mined land was successful with average heights being 9.4 feet, 6.4 feet, and 13.0 feet respectively after a five year period(6). Based on this data marketable timber could be produced in 25 to 35 years.

Bengston, Mays and Allen(7), studied the effects of timing of seeding and fertilization on the growth of pine-grass mixtures and reached the following conclusions: (1) if erosion is not a problem, seeding pines alone provided the maximum number of pine stems per acre with a maximum rate of height growth, (2) if erosion is not a problem and mixed pine-grass is desired, seeding and fertilization of pine in April followed by seeding of fescue or bermudagrass one year later yielded the best results, and (3) if erosion is a serious problem, seeding bermudagrass in the late spring followed by planting one year seedlings during the second or third year after the vigor of the grass has declined was effective.

As the primary objective of revegetation is the reduction of sediment production, grass cover must be established as rapidly as possible. According to the information available, only black locust has a high survival rate when direct seeded with grass. Thus, a one-step seeding approach appears to be limited in its applicability. Also, hand-planting of one year pine seedlings with grass has not been highly successful(7). More research should be performed to determine what softwoods and hardwoods will survive direct seeding with weeping lovegrass or another noncompetitive grass. The results of these studies will aid in determining if reforestation is economically feasible for mined land. Planting seedlings two to three years later increases the cost of reclamation, making the project economically unattractive. Unless additional incentives are created, mining companies will probably find the prospect of uncertain returns in 25 to 40 years not worth the additional effort and cost.

Trees have been planted on surface mines and coal refuse banks in Appalachia over the years and many tree stands are 25 to 35 years old. Undoubtedly some of the tree planting was performed with forest products utilization in mind, but no reports of harvestation for profit were uncovered. In almost all cases, the trees were established without a competing ground cover, although a volunteer ground cover developed later in some areas. Present reclamation practices indicate a ground cover must be established first to limit the effects of sedimentation and mine drainage.

It should be recognized there are vast differences between a forest products industry operation on unmined land operated for profit and one developed on mined land. A typical forest products operation consists of well managed large land holdings with tracts connected or in proximity to each other. Many operations cover hundreds of square miles. In the Monongahela River Basin, surface mines are not relatively large, although there may be many in one geographical area.

A typical forest products operation is in an area which has been a forest for possibly thousands of years without the ground surface being disturbed. Soil conditions are suitable for the types of trees growing and a forest mat has developed which is not disturbed during harvestation. There is no difficulty in reforesting the area after timbering either by direct seeding or the mechanical planting of seedlings. The chemical properties such as acidity, total soluble salts, and soil nutrients are in balance. The forest mat composed of organic material serves as the nutrient source which is supplemented by the organic life of the forest. The operation is large enough and the age of the trees are variable enough that in a well managed operation there is selective removal of timber.

Reforestation of area surface mines covering large acreages may be profitable, but this situation does not exist in Appalachia. This method of reclamation should be considered in the midwest and western states where large area surface mining operations are conducted.

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COAL WASTE UTILIZATION
HISTORY, RESEARCH AND PROGRESS

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COAL WASTE UTILIZATION
HISTORY, RESEARCH AND PROGRESS

INTRODUCTION

Coal mine waste has been a serious problem since the early 19th Century. In the early days of coal mining, much of the waste, particularly in the anthracite fields of Pennsylvania, could be attributed to a lack of markets for the finer size coals and also to the primitive methods of mining and coal preparation. Many technological advances have been made through the years which improved the efficiency of mining methods and coal preparation. These improvements have led to a reduction in the percentage of coal ending up in refuse piles or, in some cases, in preparation plant slurry settling ponds. Markets were developed for the finer size coals and as improved methods of coal preparation were developed, many an old refuse pile was processed for part of its coal content. Some of the mine waste has been utilized in underground stowage to prevent mine subsidence or as support during deep mining so that a larger percentage of coal could be won. The material has been used locally as landfill and red dog (burnt refuse), the end product of burning refuse banks, has been acceptable as a material in highway construction and other uses. From time to time some coal waste has been used in the manufacture of bricks, blocks and lightweight aggregate.

In spite of the technological advances in mining and preparation methods and the occasional utilization of coal refuse, one hundred fifty or more years of increasing mining activity have led to an accumulation of an estimated three billion or more short tons of coal waste exposed on the surface of mining areas in the United States. The extensively mined Monongahela River Basin has more than its fair share. It is only within the last ten years that a concerted effort has been made to alleviate the coal refuse disposal problem by emphasizing the potential for using this material in applications where large volumes could be utilized.

CONCERN WITH COAL WASTE IN THE 19TH CENTURY

Almost from the inception of coal mining in the United States, official and private reports, technical publications and editorials have been concerned with the waste of coal mining. An indication of this concern is a report prepared by a Commission appointed by the Commonwealth of Pennsylvania in 1889 to investigate the waste of coal mining with a view toward utilization of the waste(1). The appendices of this report include the following:

1. A total of 134 references to official and private reports, engineering society publications, technical journals and textbooks published between 1884 and 1892 discussing and recommending utilization of coal waste;

2. A total of 82 patents issued between 1855 and 1892 for methods of utilizing or burning fine coal sizes and coal waste;

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3. A total of 89 patents issued between 1837 and 1892 pertaining to the utilization of fine coal and coal waste in the manufacture of artificial fuels by combining with various materials such as animal blood, quicklime, sawdust, indian corn meal, molasses, peat and wheat flour to form briquettes, eggettes or other types of compressed fuel;

4. Approximately 500 references to combustion equipment and methods of burning fine coal sizes and coal waste.

The 19th Century engineering and technical publications and editorials were concerned with many of the same waste disposal problems and solutions which face us today, although the emphasis was on utilization of fine coal sizes. The publications included such topics as: compressed coal (1862); report of a committee of the American Institute of Mining Engineers on the waste of anthracite coal (1871-73); utilization of coal waste (1872 and 1876-77); manufacture of artificial fuel at Port Richmond, Philadelphia (1878); utilization of coal waste in agriculture (1885); pulverized fuel (1888); utilization of coal waste for the manufacturing of gas (1888); using mine waste to support the roof of deep mines so that coal pillars can be robbed (1889); and the processing of coal refuse banks at Winton and Plymouth, Pennsylvania (1892) - References[2-11].

The five members that served on the Commission were very knowledgeable of the problems associated with mining of coal and were very much interested in finding ways to limit the waste of coal mining either by improving mining and coal preparation methods and/or utilizing the waste for useful purposes. Mr. J. A. Price was one of the first in Pennsylvania to fully realize the importance of utilizing the great accumulations of coal waste. He was a persistent advocate of its value and did much to bring it into use in many industries of the State, particularly in the neighborhood of his hometown, Scranton. Mr. Price studied the subject with a great deal of care, had made many experiments, and was familiar with all its branches. Another member, Mr. Peter W. Sheafer, had for many years been specially interested in the question of the utilization of coal waste banks and in all improvements in mining tending to diminish the loss of coal.

When the report was written, some of the coal operators with improved cleaning facilities were processing a portion of their waste banks through the breakers with the fresh mined coal. Many of the old coal waste banks were yielding as high as 75 percent good coal. This processing of old coal waste banks in the Anthracite Region has continued to the present time, and everytime there has been improvement in coal preparation; or a new market, such as pulverized coal for utilities; or a crisis, such as World War I or II, the banks have been reworked again.

The major coal waste problem in this era was the lack of markets for the finer sizes of anthracite coal. At the most only two or three of the larger sizes had a substantial market. The finer anthracite sizes were in competition with bituminous coal, generally sold as "run of the mine," and other cheap fuel sources. The railroads controlled much of the anthracite production and the higher rates of transportation for anthracite had a tendency to restrict the market. It was not until the 1880's that the railroads encouraged the utilization of fine sizes of anthracite by lowering transportation rates. In consequence, there was a great increase in the use of the fine sizes, but this was not entirely due to rate reduction but also to a public awareness of the value of these fuels and the inventions of special furnaces and other facilities to utilize them.

Only a few years before the Commission published its findings, everything below pea size (approx. 7/8 - 3/8 range) was thrown on the refuse piles. There were no power plants in operation which successfully used pulverized fuel, but the Commission stated, "it seems probable that before long everything but the actual dust will be used." Although pulverized fuel is being used in most modern coal fired plants, the prophecy has not occurred because coal is still being wasted, particularly when an operator does not have a present market for it, e.g., a market for metallurgical grade but none for utility coal. Also, coal is being wasted in the coal preparation process. Even the most modern preparation facilities are not completely efficient and many operators do not have these modern facilities or the variety of preparation equipment needed to handle the various sizes of material.

In the latter part of the 19th Century fine anthracite became a favorite fuel for steamboats and an important locomotive fuel. Small quantities of fine anthracite were being used in burning lime, in gas producers for a number of purposes, and with bituminous coal as a mixture for heating some large buildings in major cities. Although large quantities of compressed fuel were being made and sold at a profit in Europe for years, the manufacturing of this material was not very successful in the United States. On the subject of compressed fuel, the Commission was of the opinion that it would be better to spend money on the equipment to burn the fine coal for manufacturing purposes, than to spend it to put the fine coal in shape to be burned in an ordinary furnace.

The Commission expressed the opinion that a large percentage of the coal refuse banks could be used for power production at a profit if they are burned where they exist and do not have to bear the expense of transportation - "The inferior coal should not be taken to the point of consumption, but the point of consumption should be brought to it." It is interesting to note that just a few years ago, one of Pennsylvania's electric utility companies planned to construct a 300 megawatt generation plant in the anthracite area which would use about 70 million tons of coal refuse over a 30 year period(12). A prototype unit which would provide the initial technology for commercial application of standard 30 megawatt generating units was recently constructed at Rivesville, West Virginia. The fluidized bed boiler designed by Pope, Evans and Robbins and financed by the Office of Coal Research is capable of burning coal refuse with the elimination of nearly all objectionable pollutants(13).

A unit of this type possibly could be mounted on railroad flat cars and transported to coal refuse disposal sites. After the coal refuse is consumed at one site, it could be moved to the next.

Fine coal waste was being washed into streams from waste piles and coal preparation plant operations. In some areas where pools or dams occurred, the fine coal was dredged out and used or sold. This was being done on a large scale at Northumberland, Pennsylvania where there was a dam across the Susquehanna River. A fortune has been made by the Commonwealth of Pennsylvania and the private sector in the 20th Century by dredging the Susquehanna and other streams in the Anthracite Region for recovery of coal silt. As recently as June, 1972, large amounts of coal silt were deposited in the Schuylkill River during Tropical Storm Agnes, which caused widespread devastation in the Anthracite Region(14). The Pennsylvania Department of Environmental Resources contracted for the removal of this coal silt at a profit.

A large amount of fine coal was being utilized by filling up partially worked out mines, either for greater coal recovery or for subsidence prevention(10). A large part of the City of Shenandoah, Pennsylvania was protected from the effects of mine subsidence in this way. Coal refuse was being used for grading railroads, construction of roads and for filling subsidence depressions. The Commission questioned the wisdom of using valuable fine coal deposits to backfill mine workings when less valuable materials such as silt and sand could be used in their place.

THE 20TH CENTURY BEFORE ABERFAN

President Theodore Roosevelt, one of the leading conservationists of his time, called the First White House Conference of State Governors in 1908 to discuss conservation of the Nation's natural resources. At the personal request of the President, Dr. Israel C. White, the first State Geologist of West Virginia, delivered a poignant address on May 13, 1908 titled "The Waste of Our Fuel Resources." This address(15) was a highlight of the conference, and although presented 67 years ago, little has changed and the flagrant description of the waste of our fuel resources holds true today. The poignancy of his words are typified by the statements, "The wildest anarchist determined to destroy and overturn the foundations of government could not act in a more irrational and thoughtless manner than have our People in permitting such fearful destruction of the very sources of our power and greatness," and "What will it profit this Nation to have won the wreath of industrial supremacy, if in our thirst for gold and sudden riches we permit corporate greed, as well as individual avarice and selfishness, to waste and devastate the very sources of our prosperity?"

The address was concerned with the broad overview of the appalling waste of gas, oil and coal, and not specifically with coal waste utilization. Dr. White pointed out that more than 50 percent of our deep mined bituminous coal is irretreivably lost because of mining methods still being practiced today. In reference to coal waste piles, he suggested they should be utilized through the agency of producer gas as the practicability of converting these "impure coals" into great sources of power have been fully demonstrated. "If in all new installations provisions were made for the use of gas-engines a large portion of these impure coals could be utilized, and our purer types of fuel could be preserved for other purposes."

The literature on coal waste utilization up until 1966, the year of the Aberfan disaster, is very well summarized in Peters, Spicer and Lovell(16) which contains an extensive bibliography on the subject. Although concern for the coal waste disposal problem was expressed for about one hundred years, it is apparent there was very little activity in coal waste utilization until the 1950's. Coal waste was utilized down through the years to some extent, but only when there appeared to be an economic incentive. These economic incentives were few and far between in times of cheap and easily won energy sources, and when there were only feeble cries for environmental sanity and conservation.

Probably the greatest utilization of coal waste is for the secondary recovery of coal, but this does not solve the disposal problem because 80 to 90 percent of the residue still remains on the surface of coal mining areas. After World War II, various technical and economic factors accelerated the reworking of anthracite refuse banks and coal silt deposits for the recovery of commercial quality coal(17-24). Charmbury(25) indicated that 80 million tons of coal refuse resulted from the production of about 515 million tons of bituminous and anthracite coal in the year 1957 alone. This refuse contained coal which would have been marketable if better coal preparation facilities were in use.

Since World War II, the direct burning of coal refuse banks to produce power has been practiced in Europe. France has used up its anthracite refuse banks as a source of fuel in the Ingafluid boiler which burns coal refuse crushed to approximately 1/4 inch size(26). Refuse with a dry ash content as high as 40 percent and a heat content as low as 7,500 Btu was found to provide satisfactory fuel. A power plant was designed and constructed to burn coal refuse in Scotland in the 1950's(27). Plants have been constructed in Hungary to process coal refuse for low grade fuel (20 - 40 percent ash) and the residue is used in the manufacture of brick, lightweight aggregate and cement, and as a material for hydraulically backfilling mined out areas(16, 28, 29). Utilizing the Hungarian process, Poland was recovering 400,000 tons of coal in 1967 with a throughput of 3.5 million tons of refuse(16). A pilot plant was constructed by the Pennsylvania Department of Mines and Mineral Industries (now part of Department of Environmental Resources) in the 1960's at Scranton, Pennsylvania to process anthracite refuse to obtain low grade utility fuel and noncombustible underground stowage material(30). A similar plant was located in the bituminous area near Barnsboro, Pennsylvania and operated by Pennsylvania State University(31).

The only other significant use of coal refuse prior to the Aberfan disaster was as a material for underground stowing. It has been used to control mine subsidence(32), to increase the yield of coal from old mines by hydraulically flushing the refuse with a mixture of sand and gravel(33), and as a material for extinguishing underground mine fires. Since 1955, a number of subsidence control projects have been completed in the Anthracite Region of Pennsylvania as part of "Operation Backfill" using crushed coal refuse as the medium in hydraulic flushing projects(32).

About 1961, a comprehensive program considering various realistic approaches to determine the characteristics and industrial uses of anthracite coal refuse was started at Pennsylvania State University by Dean Emeritus D. R. Mitchell and Dr. H. B. Charmbury(16). This program was initiated for the purpose of developing uses for coal waste which could contribute an economic return. An industrial complex was envisioned based upon resolution of the refuse disposal problem which would enhance utilization and develop a situation which would create employment and industrial wealth. Investigators had previously studied selected uses of coal refuse, but this was the first comprehensive program considering the broad aspects of the subject.

The program included a literature search on the subject of coal waste utilization, an inventory of anthracite coal waste disposal sites to determine the magnitude of the problem, and a series of studies on the composition and characteristics, physical and chemical parameters, and methods of preparing anthracite refuse for expansion of existing markets and development of new markets. Coal waste was evaluated for utilization as a material for landfill, highway and general construction, and for underground stowing, as a raw material for cement, bricks, lightweight aggregate, soil conditioners, mineral fillers and other uses. The secondary recovery of commercial coal and utilization of coal refuse as a low-grade utility fuel were also considered. The program resulted in a number of publications including studies on the manufacture of lightweight aggregates(34), underground stowing(35), highway construction materials(36), and a survey of the location, magnitude, characteristics and potential uses of coal refuse(16).

The U. S. Bureau of Mines in 1966 conducted a detailed survey of anthracite coal waste disposal sites in northeastern Pennsylvania which significantly updated the Pennsylvania State University Survey(37). This survey measured the impact the presence of coal waste banks has on the regional economy, environment and inhabitants. The study covered the location of refuse material in relation to the nearest community, the area occupied by each bank and the volume of material involved, and the type of refuse in each bank including the size range of the material.

The study discussed anthracite refuse disposal (removal and utilization) practices and their effectiveness and new approaches to solving the aesthetic problems. It was noted the quantity of refuse material is being diminished to a minor extent by the reclaiming of marketable coal, but that the recovery of salable coal from refuse banks seldom exceeds 20 percent, although it may exceed 40 percent from coal silt deposits. Secondary coal recovery does not offer a solution to the disposal of the balance of the residue. The three practical methods recommended for ridding the surface of anthracite refuse were to use the material for: 1) backfilling abandoned strip mine pits, 2) hydraulic backfilling of abandoned underground mines, and 3) landfill for housing or industrial developments.

THE ABERFAN DISASTER AND WHAT FOLLOWED

Interest in the utilization of coal mine waste in applications where large volumes are required did not occur until after the Aberfan disaster in Wales. In October, 1966, a coal refuse pile slid onto a school killing many children. Sliding coal refuse piles had plagued Wales and other coal mining areas in Great Britain for many years. Several investigations into the cause of coal refuse pile failures had been performed previously, but it took a disaster of this magnitude before a concerted effort was made by government and the public to prevent a future occurrence of an Aberfan tragedy. In addition to the many investigations on coal waste pile stability and design performed by individuals and organizations following Aberfan(38-42), a cooperative research effort by the National Coal Board, the Ministry of Transport through the Road Research Laboratory, and others led to the utilization of large volumes of coal waste in construction of highways, landfills, dams and other uses(13, 43-50). Many millions of tons of both unburnt and burnt coal refuse have been used in Great Britain since Aberfan in highway construction and for landfill.

In the United States during this period, Pennsylvania State University continued its studies on coal waste utilization. With the U. S. Bureau of Mines providing most of the funding, a project titled "Operation Anthracite Refuse" was performed between May, 1968 and December, 1972. The research project was performed by the Coal Research Section of the College of Earth and Mineral Sciences with the objective of establishing approaches and capabilities for use and removal of refuse from anthracite mines by determining the characteristics, methods of beneficiation, economic value, utilization, and disposal of current and insitu refuse(12).

The project resulted in the publication of ten special reports and at least twelve technical publications which are listed in the above Reference. Three completely new uses for incinerated anthracite refuse were developed. With proper crushing and sizing the material was approved for Pennsylvania Department of Transportation use in place of cinders for anti-skid material on snow covered and icy roads. The same size material can be used as a substitute for aggregate in roadway blacktop surfacing, and finally this same size was found to be suitable as a soilless medium for the growth of plants and flowers. Transportation studies indicated it would be possible to ship the material as far as the New York, Baltimore and Philadelphia areas to be used as soilless media in greenhouses.

Possible future uses would be the utilization of raw coal refuse as a base material for road building in the Poz-O-Pac process and as a substitute for slag in the production of mineral wool. A third use would be incinerated material as a substitute for aggregate in moto-paving patching of highways. Work on the project also encouraged the current uses of raw coal refuse in Pennsylvania. These include stowing of the material underground to prevent surface subsidence, the utilization of the material as a low-grade fuel, and the substitution of incinerated refuse for cinders in the manufacture of cinder blocks.

Many other possible uses were investigated but found to be unsuccessful or not economical, such as production of bricks, manufacture of cement, extraction of minerals or chemicals, and use of refuse as a filter and filler material. The project was also concerned with establishing vegetation on refuse material and results indicated vegetation could be grown successfully on incinerated refuse and silt basin refuse, but vegetation of raw refuse banks was not too successful. The socio-economic aspects of anthracite refuse in Eastern Pennsylvania were also investigated.

The Office of Coal Research (OCR) and the Pennsylvania Department of Mines and Mineral Industries (now part of Pa. DER) entered into a contract with Dorr-Oliver Incorporated to investigate the economic potential of anthracite refuse calcined in a fluid bed reactor(51). The process used the carbon in the coal refuse as a source of energy. Between 1966 and 1969, the calcined refuse was tested for use as a material in brick making and for materials in highway construction (soil bituminous and soil-cement). Bricks fabricated using the OCR-West Virginia University process were of good quality, but the process was not economically feasible at the time.

The results of bench scale studies did not justify proceeding with construction of a pilot plant. It was concluded that production of calcined anthracite refuse material, even under the most stringent conditions of quality control, in all probability would result in a product with a considerable amount of chemical and physical variability. If a commercial plant was feasible, waste heat would be recovered as steam and its value applied as a credit.

THE BUFFALO CREEK DISASTER AND WHAT FOLLOWED

It is ironic a tragedy similar in nature to Aberfan had to occur in the United States before government and the public were committed to a policy of coal refuse utilization and improved regulation of coal waste disposal sites. Just as in Great Britain, the Appalachian Region had been plagued for many years with coal waste pile failures, but the failures occurred in isolated areas with little loss of life or property damage. The failure of a coal waste impoundment in February, 1972 on Buffalo Creek in West Virginia took many lives and caused great property damage. Immediately following the disaster, a Department of Interior Task Force was organized to make a rapid study of mine waste impoundments and coal waste dam hazards throughout the Appalachian Region(52). Studies were performed by the U. S. Army Corps of Engineers(53, 54), the U. S. Geological Survey(55), the U. S. Bureau of Mines(52), state agencies, citizen groups(56) and engineering consultants(57). These studies and others(58, 59) led to greatly increased knowledge of the engineering properties and principles of design for coal waste piles and impoundments. There is now stricter enforcement of existing regulations and additional new legislation has been promulgated to prevent another Buffalo Creek or Aberfan type tragedy(60-64). The studies sparked an interest in large scale utilization of coal waste in engineering construction and created an awareness of European technology in this field.

The most significant accomplishment in coal waste utilization is the lead taken by the Pennsylvania Department of Transportation in formulating a program to study the engineering properties of coal waste and to use this material in highway construction whenever it is economically feasible to do so. Coal waste has been selectively used in construction of highways in the Anthracite Region since at least the 1960's, but it was not a standard practice sanctioned by the existing highway specifications. It was mostly used for fill and embankment construction in areas where the only material available for construction within a reasonable haul distance was mine waste. Some of the Pennsylvania highway projects where coal waste was recommended and used for construction prior to the Buffalo Creek disaster area:

1. Legislative Route 1005, Section 4-2 (Interstate 81)
   This section of roadway near Hazleton in Luzerne County had embankments 40 to 50 feet in height constructed of breaker refuse in five foot lifts. The outside slopes were covered with ten feet of soil(65).

2. Township Road 54
   Between Mahanoy and Gilberton a section of roadway embankment up to 30 feet in height was constructed mostly of coal refuse(65). The project was in Schuylkill County.

3. Legislative Route 1005, Section 2-3 Revised Alignment (Interstate 81)
   Coarse mine rock and breaker refuse within the right-of-way was recommended for use in construction of this roadway south of Hazleton in Luzerne County(66).

4. Legislative Route 786, Section 3
   The removal of 200,000 cubic yards of culm, fine coal and organic silt in the flood plain of Nanticoke Creek was recommended; the material to be replaced with mine waste rock and coarse breaker refuse. This project was located south of Wilkes-Barre in Luzerne County(67).

5. Legislative Route 786, Section 4
This section of roadway south of Wilkes-Barre in Luzerne County consisted mostly of embankment construction across an extensively mined area covered with mine waste deposits. The Blue Coal Colliery in Ashley was reworking breaker refuse piles for secondary coal recovery and the processed material was recommended for embankment construction(68).

6. Legislative Route 1005 (Interstate 81)
Coal refuse with bituminous material was used for construction of shoulders near the Dunmore Office of the Pennsylvania Department of Transportation. The office is located near Scranton in Lackawanna County(65).

In the spring of 1973, a cooperative agreement was worked out in Pennsylvania between the State Departments of Transportation (PennDOT) and Environmental Resources (DER) for the utilization of coal waste in highway construction. As a result of the agreement about 1.5 million cubic yards of coal refuse were used in embankment construction of the Cross Valley Expressway at Forty Fort, Luzerne County, in the Northern Anthracite Coal Field of eastern Pennsylvania. The percentage of unburnt and burnt (red dog) refuse used in embankment construction is estimated to be about equal in proportion(69, 70).

A second project utilizing coal waste proposed for the Northern Anthracite Coal Field is a section of the Lackawanna Valley Expressway between Scranton and Carbondale, Lackawanna County, Pennsylvania. This project is in the preliminary design stage, but it is estimated anywhere from three to seven million cubic yards of coal waste could be used in construction of the highway.

In the bituminous coal region of western Pennsylvania, PennDOT has proposed at least three projects:

1. East of Monessen, Westmoreland County, it has been proposed to extinguish the fires in a burning refuse bank by covering the bank with waste excavation from a nearby roadway cut. An industrial park may be developed in this area.

2. A coal refuse pile near California, Washington County, may be used for highway fill in the flood plain of Pike Run.

3. Two of the larger coal refuse banks in western Pennsylvania, the Revloc banks of the Bethlehem Mines Corporation, near Ebensburg, Cambria County, are proposed for fill and embankment construction in the modernization of Routes 219 and 422. An examination of the banks indicate they may contain up to 50 percent recoverable coal. The banks will be processed for coal before being used for highway construction and it is estimated about four million cubic yards of processed refuse will be available. The Bethlehem Mines Corporation is donating the refuse and they have donated the land upon which the refuse banks lie to the county for development of an industrial park.

EPA in conjunction with West Virginia University and the Monongahela Power Company in 1973 used a coal refuse and fly ash composition in construction of a demonstration parking lot at the EPA Drainage Control Field Station in Crown, West Virginia(71).

The ARC in 1974 made a grant to the West Virginia Department of Highways which will underwrite, in part, the initial studies by this state on the utilization of coal mine refuse in highway construction(72).

West Virginia University is performing an investigation funded by the Office of Coal Research titled "A Study of Coal Associated Wastes Resulting from the Mining, Processing, and Utilization of Coal." The purpose of the contract is to investigate all wastes and byproducts associated with the conversion and utilization of coal, to characterize them both physically and chemically, to investigate possible utilization processes, and to suggest safe disposal methods for these materials(72). Research completed so far has indicated:

1. A coal waste-asphalt concrete material can be produced which may be suitable as a road base.

2. Cement-coal waste products similar to mine stoppings can be prepared which have high compressive strengths and appear fire resistant.

3. Both coal refuse bank material and associated coal fines appear to be amenable to flotation beneficiation for the recovery of usable products and the removal of sulfur constituents. The high Btu content of coal fines indicate that this material could serve as a fuel or fuel admixture if a suitable dewatering technique can be developed.

4. A process developed called "Sulfurtain" could make it possible to utilize coal fines, minus 28 mesh material resulting in cleaning operations, for fuel without the threat of sulfur dioxide pollution. Generally this fine material is discarded as waste because of its high sulfur content. The fine material is high in carbon and Btu values are on the order of 10,000 or greater. The process involves intimately mixing the fine coal with an alkaline earth material such as lime; when the mixture is burned, the sulfur is retained in the ash(73). Since the coal industry produces about 100 million tons of waste material annually and a considerable portion of the material exists as moderately high Btu fines, this could be a significant process if further research indicates it is economically feasible.

As part of the study, a literature survey containing over 1,000 references on the utilization of coal associated wastes was prepared. A report titled "Gob Pile Stabilization, Reclamation, and Utilization(74) was prepared in 1973.

THE NATIONAL COAL BOARD OFFICE OF "MINESTONE EXECUTIVE"

In 1970, the National Coal Board (NCB) of Great Britain established an office called the "Minestone Executive" for the purpose of maximizing the commercial disposal of coal refuse materials. The Minestone Executive is charged with the obligation of removing as many coal refuse piles as possible at a profit. It is interested somewhat with environmental aspects, but refuse removal without income is of secondary interest. Sales range from small local bulk purchases to large markets for millions of tons for highway projects. The usual selling price to contractors is about \$0.25/ton(75, 76, 77).

The staff of the Minestone Executive is composed of men with both a technical background and sales experience. The NCB experience in selling coal refuse has indicated the necessity for technical assistance in the proper utilization of this material cannot be overemphasized. It maintains close liaison with the Department of the Environment and one of the most encouraging developments from this has been the introduction of a system of "duel tendering" for material used in highway construction in the mining districts. Contractors are asked to submit tenders (bids) with one set of prices based on the use of minestone (unburnt coal refuse) in addition to pricing with their own choice of material. Millions of tons of coal refuse have been removed in this way.

The NCB has issued a brochure(78) to help promote the disposal of coal refuse, part of which is presented on page IV-18, and NCB Minestone Executive advertisements regularly appear in the New Civil Engineer, the magazine of the Institution of Civil Engineers, examples of which are presented on pages IV-19 - 22.

Dr. Maneval has said, "It is not unreasonable to suggest that similar technical, marketing, and service efforts in the United States would help the coal industry with its solid waste disposal-environmental problem and could provide a needed useful source of fill and ceramic raw material(75, 76)."

CONCLUSION

The purpose of this section was to present some of the highlights of the history, research and progress on coal waste utilization. It is not a complete documentation of efforts made to solve this very challenging problem. It is apparent that although the coal waste disposal problem has been with us for about 150 years, it only within the last ten years that a concerted effort has been made to come to grips with the problem.

Our dependence on coal will be much greater in the years to come. It is imperative that mining, coal recovery and disposal methods be greatly improved if we are to meet the challenge of a better environment and energy independence by 1985. The picture presented by Dr. White in his address before the First White House Conference of State Governors in 1908 may have changed some, but most of the waste he referred to is still occurring. This address, "The Waste of Our Fuel Resources," presented 67 years ago can be read with much profit today.(15)

There are very few villains in the waste of our natural resources. It has always been a question of cheap energy, i.e., what people would pay for their energy sources. If we want to eliminate waste and have a clean environment, it will cost us, and we must be willing to pay the price. If we want to greatly increase coal production in the next few years, answers must be found to the problem of making less profitable mining operations competitive with the more profitable ones. This problem is critical in the Appalachian Region.

It is realized coal is not a migratory fluid or gas, but it is possible the coal industry can learn a lesson and profit from the experience of the oil and gas industry. Out of necessity, oil and gas fields are developed as a unit because the fuel resources do migrate and uncontrolled withdrawal by some could endanger the interest of others. Profit sharing is based on individual interest in the venture. A drainage basin or geographical area concept should be considered in developing our coal reserves to the fullest. This would require pooling of resources to develop total mining concepts where all coal seams within the area are mined with the objective of maximizing coal recovery, limiting waste, and developing markets for the waste that cannot be prevented.

NATIONAL COAL BOARD brochure "Colliery Shales"

There are two types of colliery shale. Black shale (minestone) is most often used as bulk fill. Red shale offers more versatility and comes from older tips, where combustion has occurred due to the lesser understanding of contributory factors in earlier times. Black shale (minestone) is the raw shale as raised from the mine. Modern techniques of coal separation and tip construction are such that combustion does not take place.

Both types of material are available in vast quantities which are easily won without costly quarrying operations such as blasting and crushing.

The established network of shale contractors ensures that delivery of material at a site is efficiently carried out whether the order is for a few tons of graded material for a private drive or for a million tons for a motorway project.

Part of Page 2
"General Information"

Road Research Laboratories have contributed to the examination of colliery shales and have published reports on their work. (Ref. Page 12.)

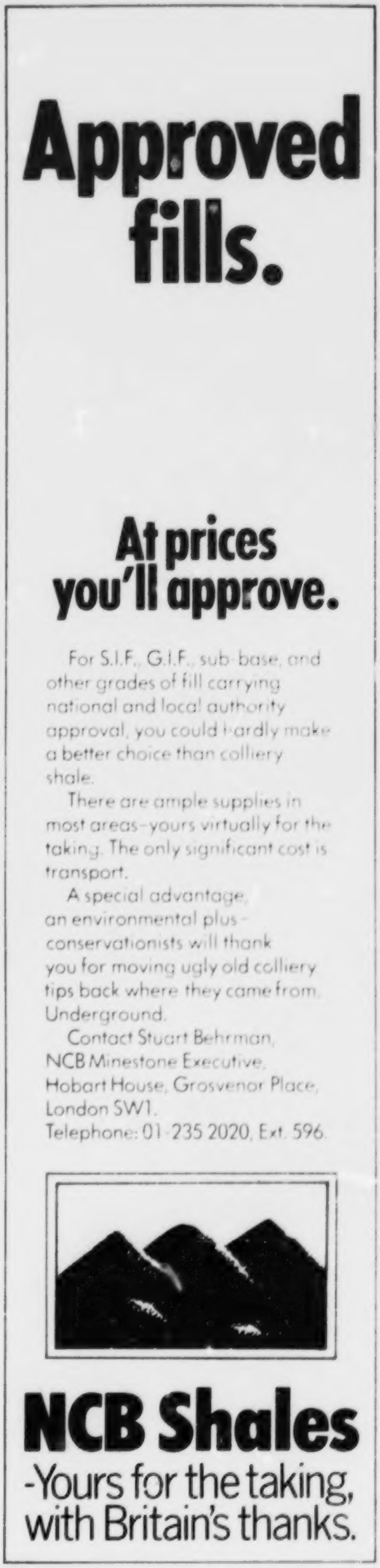
Both materials now have MOT approval, per MOT Tech. Memo. T4/68.

Shale is generally appreciated by road-building contractors, who find it economic in use both in terms of delivered cost and of final cost resulting from its convenience and speed in use. Red Shale is welcomed as an upper layer, since it provides a clean, dry running surface in all weathers.

The nation's shale heaps offer vast resources of low cost fill material. In using shale, engineers can feel satisfied that they have contributed towards improving the environment and to the national economy. This is particularly relevant now that there is ample practical experience in the use of this material.

Major road construction is currently running at a high level which must inevitably decrease with time. The price of failing to make use of colliery shales at every opportunity is very high. It is the cost of the eventual removal of pit-heaps at public expense. It includes the cost of dealing with more dereliction which defaces our landscape, taking valuable and needed space in the course of winning alternative materials.

Part of Page 4
"Road Materials"



Approved fills.

At prices you'll approve.

For S.I.F., G.I.F., sub-base, and other grades of fill carrying national and local authority approval, you could hardly make a better choice than colliery shale.

There are ample supplies in most areas–yours virtually for the taking. The only significant cost is transport.

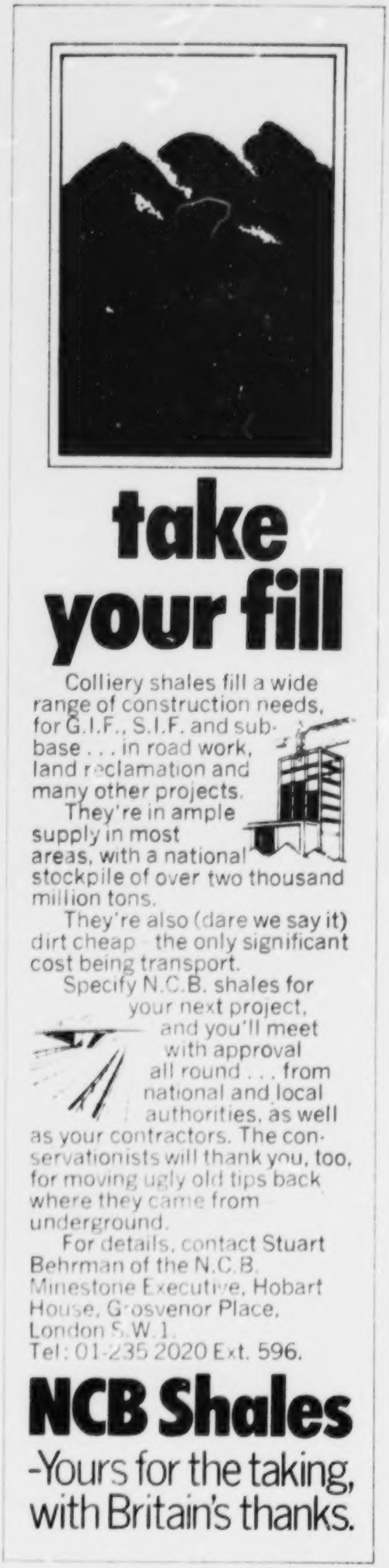
A special advantage, an environmental plus–conservationists will thank you for moving ugly old colliery tips back where they came from. Underground.

Contact Stuart Behrman,
NCB Minestone Executive,
Hobart House, Grosvenor Place,
London SW1.
Telephone: 01-235 2020, Ext. 596.

NCB Shales

-Yours for the taking,
with Britain's thanks.

New Civil Engineer, 11 October 1973



take your fill

Colliery shales fill a wide range of construction needs, for G.I.F., S.I.F. and sub-base . . . in road work, land reclamation and many other projects.

They're in ample supply in most areas, with a national stockpile of over two thousand million tons.

They're also (dare we say it) dirt cheap – the only significant cost being transport.

Specify N.C.B. shales for your next project, and you'll meet with approval all round . . . from national and local authorities, as well as your contractors. The conservationists will thank you, too, for moving ugly old tips back where they came from – underground.

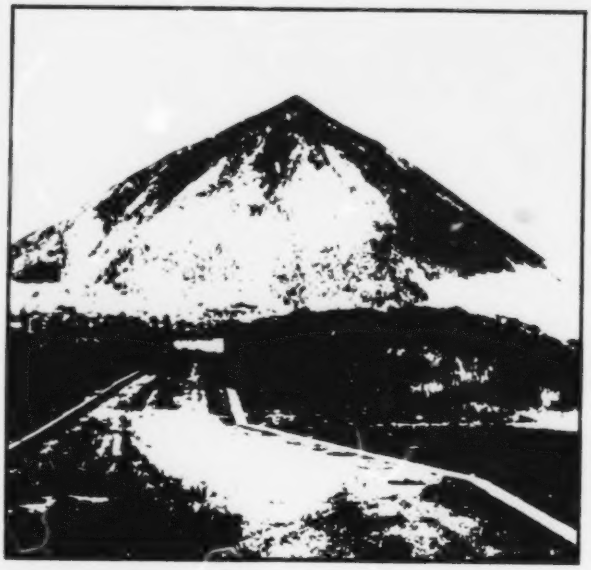
For details, contact Stuart Behrman of the N.C.B. Minestone Executive, Hobart House, Grosvenor Place, London S.W.1.
Tel: 01-235 2020 Ext. 596.

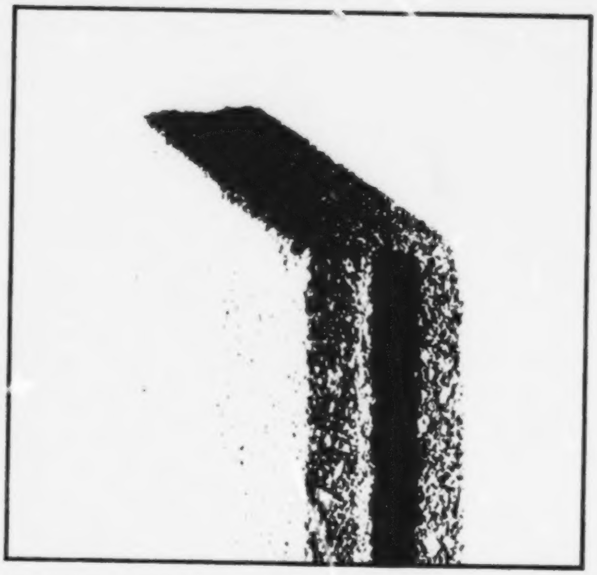
NCB Shales

-Yours for the taking,
with Britain's thanks.

New Civil Engineer, 24 January 1974

Waste not – want not.





Soon, over half a million tons a year of colliery shale will be converted into lightweight aggregate for the building industry. An import saving of over £1½m will be achieved. And unsightly mounds of shale will be converted into houses, offices and factories.

This plant is the first of many converting colliery waste directly into a valuable construction material – saving environmental dereliction and making the best use of the previously unexploitable energy potential in the waste.

The blocks made from this aggregate are called Brag blocks. You'll find out all about them from the **NCB Minestone Executive** staff at the National Coal Board Stand 01 at the Public Works Exhibition, Olympia.

BRAG

We're holding up a lot of traffic.

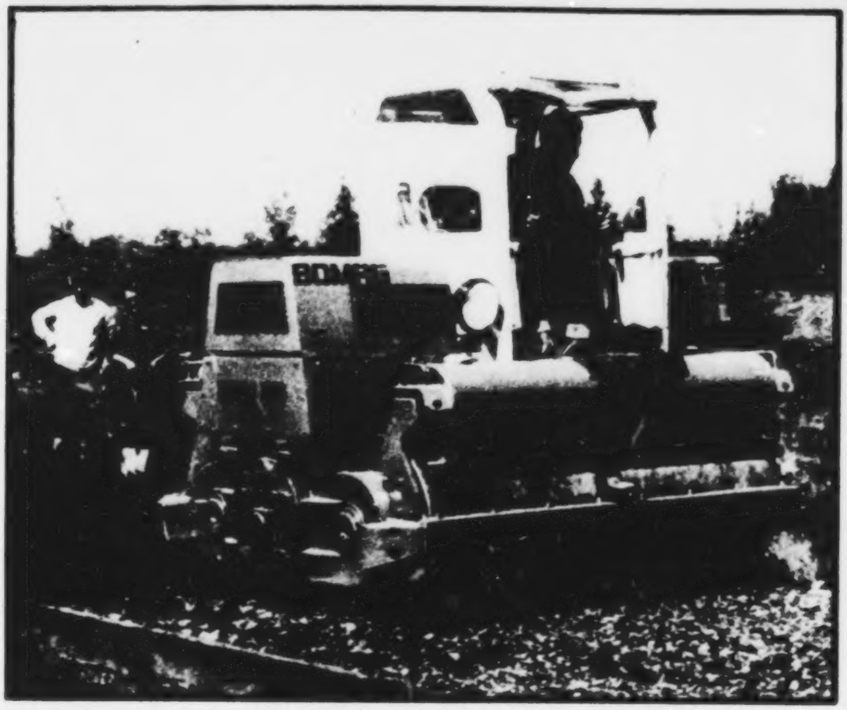
(We support motorways).

4 million tonnes of minestone were removed from the tip which occupied this 13 acre site at Thorne in Yorkshire, to act as fill for the M18/M62 motorways. As well as making good use of this material, the operation has freed land for development.

If you are interested in low cost fill, sub-base, etc. please contact:- Stuart Behrman,
Minestone Executive,
National Coal Board,
Hobart House, Grosvenor Place,
London SW1X 7AE.
(Tel: 01-235 2020 ext. 596).

NCB Shales

Rolling stone? No-rolling Minestone.



CEMENT STABILISATION of selected Minestones can provide a very good sub-base material. This is of particular interest where other sub-base material is costly; it could be used economically for base-course also in estate roads, hard shoulders, hard standing, storage areas, etc.

Pictured is compaction of one of the areas laid at field trials in Kent. The seven-day strengths of the control test-cubes comfortably exceeded the DoE minimum requirement of 500 lb/in^2.

Further information from
D. A. Tanfield, NCB Minestone Executive,
Hobart House, Grosvenor Place,
London SW1X 7AE, Tel: 01-235 2020.

NCB Shales

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THE ECONOMIC POTENTIAL FOR UTILIZATION OF WASTE COAL WITH RELATIVELY HIGH Btu CONTENT FOR POWER PRODUCTION EITHER DIRECTLY OR BY BLENDING WITH HIGHER GRADE COALS

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THE ECONOMIC POTENTIAL FOR UTILIZATION OF WASTE COAL WITH RELATIVELY HIGH Btu CONTENT FOR POWER PRODUCTION EITHER DIRECTLY OR BY BLENDING WITH HIGHER GRADE COALS

INTRODUCTION

The last part of this section, titled "Waste Coal Reclamation," was written by J. W. Leonard and W. F. Lawrence in 1972. It presents a hypothetical history of a coal refuse pile and emphasizes the heterogeneous nature of the material. The variability of material in a coal refuse pile depends on many factors, such as, the market for coal, method of cleaning, efficiency of the cleaning process, mining methods and systems employed and the quality of the coal seam. The most important conclusion to be drawn is that extensive sampling, both on the surface and at depth, has to be performed before accurate estimates can be made as to the fuel value of a refuse pile.

This paper also discusses coal refuse bank ownership; methods to be used in mapping and sampling; potential acid mine drainage reduction; possible actions that can be taken by government to encourage processing of refuse piles for secondary coal recovery and for utilization as a low grade, high ash fuel; the affects utilization of coal refuse bank material will have on power plant operations; and the economic potential for utilization of coal refuse banks in the Monongahela River Basin for production of energy.

The potential for economic utilization of coal refuse banks is based on the proximate analyses of 20 samples collected randomly throughout the Monongahela River Basin in August, 1972 by Michael Baker, Jr., Inc. The preliminary information strongly infers that a high percentage of coal refuse banks in the basin could be burned in new, modified or existing combustion processes to produce useful power with the simultaneous benefit of converting unsightly piles of refuse to greatly reduced quantities of more readily utilized ash.

In October, 1974, four additional coal waste disposal sites being processed for secondary coal recovery were sampled. The proximate analysis results are presented on pages IX-12 and IX-13 of the report. The coal shortage of last winter coupled with increased production costs have made the reworking of coal refuse banks and the recovery of coal from preparation plant slurry settling ponds very attractive. A review made at this time of Pennsylvania Department of Environmental Resources surface mining permits indicated permits have been issued for processing coal from at least 17 bituminous refuse disposal sites and there were about 35 similar operations in the anthracite coal area of Pennsylvania.

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Map Sheet 2 of 3 shows the location of over 300 coal refuse disposal areas in the Monongahela River Basin. The location of power plants are also presented. Appendix A (pages A-1 to A-58) is a preliminary inventory of coal refuse disposal areas presenting information that was readily available or could be developed from data obtained from various sources. A complete inventory of coal refuse disposal sites and all pertinent data needed for an objective appraisal of the total fuel value available, areal extent, volumes, environmental and other factors was beyond the scope of the study. The refuse bank numbers presented in the inventory forms refer to the locations shown on the map sheet.

FUEL RECOVERY FROM COAL WASTE DISPOSAL SITES

Processing coal waste disposal sites for a second yield of high grade, marketable coal has been practiced in the Anthracite Region of Pennsylvania since at least the 1880's(1, 2). There was a great amount of activity in this region in the 1930's for recovery of the finer coal sizes from refuse banks(3) for the utility market. Following World War II, various technical and economic factors again led to the processing of anthracite refuse disposal sites(4-12). Until very recently, most secondary coal recovery operations were in the anthracite area of Pennsylvania. Bituminous refuse banks have been worked from time to time for blending refuse material with current coal production. Secondary recovery of coal still leaves 80 to 90 percent of the residue on the surface of coal mining areas and is not a solution to the coal refuse disposal problem. The solution and real potential is the utilization of coal waste for low grade, high ash fuel and development of markets for the residue including the fly ash and cinders from burning high ash fuels.

The direct burning of coal waste banks to produce power has been practiced in Europe since World War II. France has used up its anthracite banks as a source of fuel and power plants have been constructed in Great Britain designed to burn coal waste(13). An electric utility company in Pennsylvania has proposed the construction of a 300 megawatt generation plant in the anthracite area which would use about 70 million tons of coal refuse in a 30 year period(14). Several coal refuse recovery operations in the United States and Europe have been designed to recover high grade and/or low grade fuel and useful end products from the residue. These processing plants indicate that it is possible to completely utilize an abandoned refuse bank. McLean, Kogelmann and Spicer(15) and Spicer(16) have described the following operations:

1. State Coal Company - Mt. Carmel, Pennsylvania(12, 17)
   The plant in operation in 1964 produced clean anthracite coal and strip mine backfill utilizing heavy media separators employing a magnetite medium.

2. Pennsylvania State University - Barnsboro, Pennsylvania(18, 19)
   The 50 tph pilot plant placed in operation in 1965 was designed to produce a salable grade bituminous coal and raw material for manufacture of construction products. The separators use a magnetite medium and a hydrocyclone was used for pyrite concentration. Indications were that

a good potential existed for producing a pyrite concentrate acceptable for sulfuric acid manufacture.

3. Pennsylvania Department of Mines and Mineral Industries Processing Plant - Scranton, Pennsylvania(20)
This 50 tph plant was identical to the Barnsboro pilot plant and was designed to produce a salable low grade anthracite coal for the utility market and nonburning refuse for underground stowing or for use as backfill. The plant was operated for about a year between 1965 and 1966 when the project was discontinued. It proved capable of attaining its objectives and construction of larger production plants was recommended as being economically feasible.

4. Kaiser Steel Corporation - Sunnyside, Utah(21)
Bituminous refuse from the coal cleaning plant is processed by screening, crushing, grinding, and blending with flotation tailings to produce mine backfill. Plant capacity is 1,500 to 1,800 tons/day.

5. Baddesley Colliery - England(22)
The plant operated by the National Coal Board processes 80 long tons/hour of refuse containing ten percent coal to recover 365 long tons of clean coal per week with 86.9 percent rejection of sterile waste. A magnetite medium is used to produce the bituminous coal and refuse containing five percent coal can be operated profitably.

6. "Manvers Main" Central Coal Preparation Plant - England(23)
This plant, also operated by the National Coal Board, was the largest operation of its kind in 1959. The plant processes 1,320 tons/hour from four collieries mining five different coal seams. The unique feature of the plant is that flotation tailings refuse is the medium for producing a wide range of coal products from a complex plant feed. The size of the operation clearly demonstrates the use of refuse as a heavy medium is an established mineral preparation technique.

7. Simonacco Ltd. - Carlisle, England(24)
This company has exclusive rights in Great Britain to the Simdex (Haldex) cyclone process for treating coal refuse, washery rejects, and other coal containing materials using a specially designed heavy media cyclone which uses fine refuse as the medium. The Simdex cyclone is the same as the Haldex cyclone which was originally developed in Hungary. Simonacco has built several portable Simdex cyclone plants in England ranging in size from 50 to 150 tons/hour.

8. Gartshire Plant - Glasgow, Scotland(25)
One of the main purposes of the plant is to provide 500 tpd of clean shale for an adjacent lightweight aggregate plant. Using magnetite as a separation medium, 2.6 million tons of anthracite refuse is to be processed between 1972 and 1976 at the rate of 2,000 tpd to recover high grade coal, middlings and clean shale.

9. Tatabanya Mine Dump Reclamation Plant - Tatabanya, Hungary(15)
This plant employing the Haldex (Simdex) cyclone utilizing refuse as a heavy medium is near ideal in its approach to refuse reclamation and recovers a wide variety of building product raw materials. The modified heavy media operation uses the fine sizes of refuse as a low cost specific gravity controlling medium. Refuse containing 10 to 20 percent coal is utilized as plant feed to produce clean coal (maximum of 12 percent ash), low grade fuel (20 to 40 percent ash) and raw material for brick, lightweight aggregate, cement manufacture and backfill.

A coal refuse processing unit which possibly could be adapted to the concept of complete utilization of coal waste material is the Renkol Coal Classifier(26). It utilizes the reverse Coriolis effect, pumping waterborne material from the slurry tank into the cyclone intake under pressure at an angle that creates a counterclockwise centrifugal swirl. Most cyclone designs swirl the material clockwise. The refuse is the medium of separation.

In 1972, Recco Coals, Inc. began operations in McDowell County, West Virginia with their pilot Renkol Coal Classifier. The refuse piles being reclaimed by Recco contain approximately 35 percent coal and the plant recovers better than 30 percent of material input. The unit can handle 230 tons/hour of refuse and is presently producing roughly 70 tons/hour of coal consistently at or above 12,500 Btu. More than a year of operation has indicated the plant has many distinct advantages, such as:

1. One man can readjust and set the cyclone for optimum separation in a matter of minutes or less while the plant is running full tilt. Once the cyclones are adjusted, it practically runs itself, with no special mechanical skills required;

2. The plant can be moved easily as it consists of five subassemblies, each of which can be fitted on a low-boy truck bed;

3. The plant is on skids and operates relatively free of vibration. Permanent footings are not required;

4. Dirty coal from either surface or deep mines can be cleaned economically and quickly in comparison to the more costly traditional fixed-site preparation plant method. Marginal coals can be upgraded into higher quality coal;

5. The plant can be adapted to deliver any size product from fines up to 2-1/2 x 0 by simple adjustments of the crusher, sieve screen and hydrocyclones;

6. The plant can be constructed to achieve the same efficiency in the separation of any mineral from refuse, so long as there is a measurable difference between the specific gravity of the mineral and the refuse material;

7. The design is such that the plant is capable of coping with virtually any mineral cleaning or classifying problem by a minimum of simple design conversions.

The Stoudt's Ferry Preparation Company, Mahanoy, Pennsylvania, is using the "specific gravity" method for recovery of coal from coal silt deposited along the Schuylkill River after Hurricane Agnes. A Classifier, a large funnel-shaped vat, is used and jet streams of water separate the coal from the mud and sand. Two similar projects operated by the company use the "shaker table" method(27).

There are distinct advantages in using the classifier as it is smaller and has a capacity of handling 60 tons of raw material per hour. Because of its smaller size, a classifier can be set up and in operation much quicker than a shaker table. A shaker table only processes about four to six tons of raw material per hour.

A piece of equipment that is proving to be highly successful in recovering coal from old slurry settling ponds is the Mud Cat, a versatile, two man operated mini-dredge developed expressly for the purpose of ridding lakes, streams and channels of undesirable sediment buildup. The dredge can reach down to 15 feet below the surface of the water and by lowering the water level will be able to go to the bottom of the coal silt deposit. It works best in 21 inches of water or more, but can be used in applications where it has to eat its way into solids.

The Peabody Coal Company is using a Mud Cat to recover coal from a slurry settling pond at their Bee-Veer mine, Macon, Missouri(28). The pond is about 100 acres in size and slurry deposits are up to 60 feet thick. The dredge is recovering 40 tons of coal an hour and presently operates seven hours a day. The slurry is pumped through a 3,000 foot long discharge pipe to the preparation plant, equipped with new processing machinery, where it is washed, dried, sorted and loaded onto rail cars and shipped directly to a steam generating plant. Nearly a million tons of coal will be recovered from this one site. The situation is common to many of Peabody's 35 other surface mines and it is estimated total possible coal recovery from their slurry ponds is somewhere close to 20 million tons.

Dr. Philip Walker, Professor of Material Science at Pennsylvania State University believes the energy crisis may help clean up the coal waste disposal problem by forcing the perfection of coal gasification technology(29). When this happens, Dr. Walker says, it will doubtless prove economical to feed coal waste and other refuse into gasifiers and use the resulting gas for industrial uses. This is not a new idea. The Commission appointed by the Commonwealth of Pennsylvania in 1889 to investigate the waste of coal mining in their report mentioned the utilization of coal waste for the manufacturing of gas, and several references in the Appendices of the report refer to gas producers(2). Dr. White in his 1908 address to the First White House Conference of State Governors recommended that coal waste piles should be utilized through the agency of producer gas(30).

RELAXATION OF EPA STANDARDS FOR GENERATING UNITS BURNING COAL REFUSE

The Environmental Protection Agency (EPA) in January, 1975 amended Section 60.44 of "Standards of Performance for New Stationary Sources" to exempt steam generating units burning at least 25 percent (by weight) coal refuse from the nitrogen oxides (NO_x) standard of performance. Such units still must comply with the sulfur dioxide and particulate matter standards of performance(31).

According to EPA, the action will affect only one planned source and is not ever expected to have wide applicability. At the time of promulgation of Section 60.44 in 1971, EPA was unaware of the possibility of burning coal refuse in combination with other fossil fuels, and thus the standards of performance were not designed to apply to coal refuse combustion.

The low heat value, high ash characteristics of coal refuse preclude combustion except in cyclone furnaces. With current technology it is not possible to burn significant amounts of coal refuse and achieve the NO_x standard performance. It appears EPA desires to encourage the utilization of coal refuse as it was noted in the release: "It (coal refuse) can prevent restoration of the land and produce acid runoff," and "Combustion of coal refuse piles would reduce the volume of solid waste that adversely affects the environment, would decrease the quantity of coal that needs to be mined, and would reduce acid water drainage, as the piles are consumed."

SOME ACTIVE COAL RECOVERY OPERATIONS IN PENNSYLVANIA

Several active coal recovery operations in Pennsylvania were visited in October, 1974. Because some of the coal operators did not want to be identified, the location is given by County only. All the operations were covered under the Pennsylvania Department of Environmental Resources permit system which requires complete reclamation of the area under permit after the coal recovery operation is completed. The coal recovery operations can not discharge silt or acid drainage into streams during the active operation, therefore, silt basins and mine drainage treatment are required where necessary.

1. Indiana County

Between 1955 and 1965, preparation plant reject was deposited in a slurry settling pond by pumping the waste to the disposal site. The reject was from processing metallurgical grade coal of the Upper Freeport seam. All of the coal silt is being recovered by a very simple method. A farm tractor with harrow is used to break up the clumps and a dozer stacks the material in windrows for air drying, the only preparation required. The coal silt after drying is loaded on trucks with a front end loader and shipped to a power plant and steel companies where it is blended with higher grade coals. Weekly production is in excess of 1,100 tons of material. The proximate analysis test results are presented on pages IX-12 and IX-13.

2. Fayette County

A coal refuse bank is being reclaimed using a dry screen (6 inch), front end loader and dump trucks. The processed material is being hauled to a coal preparation plant where it is blended with current coal production. It is anticipated that the material larger than six inches will be crushed and processed at a later time. The refuse is from preparation of Pittsburgh seam quality coking coal. Production of low grade coal material is about 500 tons/day. The proximate analysis test results are presented on pages IX-12 and IX-13.

3. Washington County

This is another dry screening operation which was not being worked at the time of the visit. Part of the refuse pile has burned in the past and red dog had been recovered previously. The Pennsylvania Department of Transportation has plans for using the cleaned refuse as a material for highway construction. The proximate analyses test results are presented on pages IX-12 and IX-13. The refuse is the reject from preparation of the Pittsburgh coal seam for metallurgical grade coal.

4. Westmoreland County

A permit had just been issued for this coal recovery operation and no equipment was at the site. Low grade fuel had been recovered from the disposal area previously for shipment to power plants for blending with other coals. The Pittsburgh coal seam was mined in this area. The proximate analysis test results are presented on pages IX-12 and IX-13. Production of coal from the refuse pile is expected to be about 500 tons/day of low grade fuel.

5. Westmoreland County

This second operation in Westmoreland County covers 44 acres and the refuse bank contains about 3 million cubic yards of coal refuse. Coal recovery is running between 30 and 40 percent of bank material. The coal refuse is loaded on to a conveyor belt by a front end loader and the material being processed at a preparation plant.

The "Coal Waste Mining Inventory Form" presented on pages V-13 to V-16 was found to be very suitable for obtaining information on coal waste disposal sites.

COAL WASTE MINING INVENTORY FORM

Project: Appalachian Regional Commission Contract No. 72-89/RPC

1. Coal Waste Disposal Site No. __________

2. Stream Basin: ____________________

3. Nearest Town: __________ County: __________ State: ____________

4. U.S.G.S. 7-1/2 Minute Topographic Quadrangle: ___________________

5. Latitude ____° _____' _____" Longitude _____° _____' _____"

6. Area: __________ Acres Estimated Volume ____________ C.Y.

7. Topographic Setting:

8. Drainage Characteristics:

9. Company or Operators Name:

10. Surface Mining Permit No. _________ Drainage Permit No. ___________

11. Property Owner(s):

12. History of the Coal Waste Disposal Site:

    a) Source of coal waste material (Name of mine(s) and/or coal preparation plant)

    b) Coal seam(s) deep mined and physical and chemical characteristics

    c) Type of roof and bottom rock in deep mine(s) and their physical and chemical characteristics

d) Years during which coal waste was placed at the disposal site

e) Market for which coal was cleaned, methods of cleaning and quality of coal

f) Mining methods and systems employed

g) Is part of the coal waste disposal site burning or has it been on fire in the past?

h) Has part of the coal waste been previously mined for:
Coal __________ high ash, low grade fuel __________ red dog
__________ or other materials (Describe)

i) If the answer to (h) is affirmative, briefly describe available information on the operation (Company or operators name, permits if required, markets for processed material, volume processed, and other pertinent information)

j) Method of coal waste disposal (tippler form, layer piling, layer piling with soil, disposal into a strip mine or depression, or other method of disposal)

13. Material presently being mined at coal waste disposal site:
Coal __________ high ash, low grade fuel __________ red dog
__________ other (Describe)

14. Market(s) for processed material:

15. Weekly production: __________ Tons

16. Estimated percentage of entire coal waste under surface mining permit being recovered: __________

17. How many acres being mined under the surface mining permit: __________

18. If the permit does not cover the entire coal waste disposal site, what are the future plans for the remaining area:

19. Equipment being used and a description of the operation:

20. Is material being processed at the mining site?
If not, where is it being processed?

21. Describe the processing operation:

22. Environmental controls during the active mining operation:

23. Final reclamation plans for the mining site and processing area:

24. Observations and other pertinent information:

25. Samples collected:

a) Engineering properties (sample numbers and estimated weight of each sample)

b) Compositional analysis (sample numbers and estimated weight of each sample)

c) Date collected: ____________________

d) Sampling and interview by: ___________________________________

WASTE COAL RECLAMATION

by

J. W. Leonard and W. F. Lawrence

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HYPOTHETICAL HISTORY OF A CULM BANK

A waste coal pile or culm bank is heterogeneous rather than homogeneous in composition and variation will occur, both horizontally and vertically. Culm bank materials in the Monongahela River Basin will generally consist of coal, shale, bone coal, sulfates, carbonates and pyrite or marcasite. In addition, slag materials may be present if combustion of portions of the bank has occurred. The relative amounts of each constituent will be dependent upon such factors as the market for which the coal was cleaned and the methods of cleaning, the efficiency of the cleaning process, the mining methods and systems employed and such natural factors as the quality of the coal seam. In order to illustrate the effects of the many variables upon the composition of the materials being placed on a culm bank, a hypothetical history of an imaginary culm bank is included. While no such bank may actually have been formed, many of its features can be seen in existing banks. Figure 1 has been prepared to show the major markets for bituminous coal from 1917 to 1956. The history of a mine and its resultant culm bank could therefore be as follows:

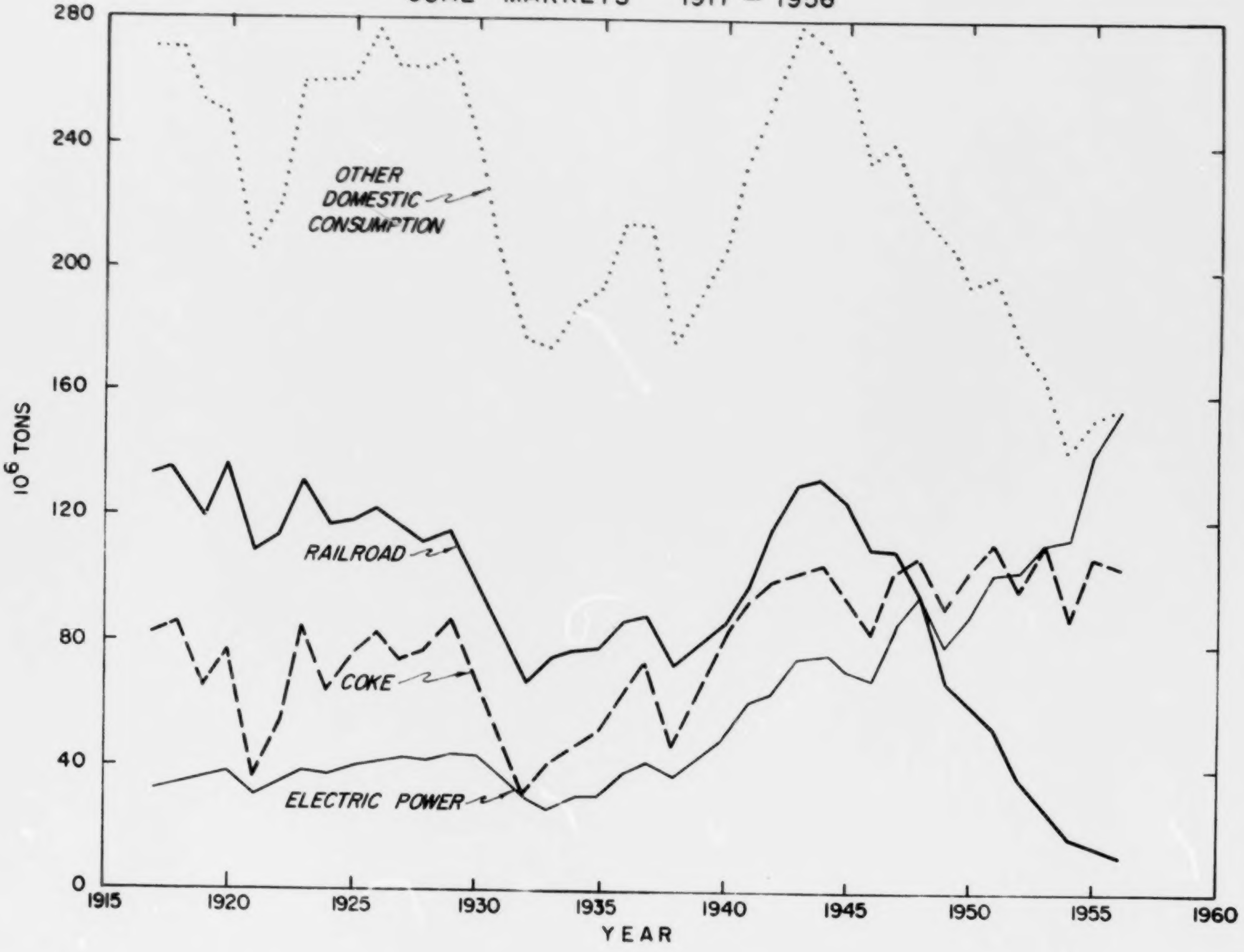
1917 - A coal mine is opened and a picking and screening facility is constructed along the Monongahela River to help supply an existing market for metallurgical and railroad locomotive fuel and for fuel for industrial and commercial heating plants as well as for household furnaces. Mining is not yet mechanized to any extent, and waste material from the picking and screening facility contains mainly hand picked pieces of rock and coaly material along with the undersize material for which no steady market exists. This fine material is predominately fuel and is mixed with the waste rejects and discarded. Due to the method of dumping, the softer, more friable materials tend to be concentrated in the interior of the pile while the harder, higher ash, hand sorted materials accumulate along the edges.

1920- Coal production and coal sales are dropping. In order to retain markets, greater selectivity in mining is employed and the preparation facility is enlarged and improved to produce a higher quality coal. Additional pickers are hired and more rigorous sorting and sizing are initiated. The ash and the sulfur content of the coal being marketed are successfully reduced, and more enriched fuel is being deposited on the pile.

1923 - A new market for intermediate quality coal develops with the construction of an electric power generating station nearby. In addition, gas and oil are beginning to replace lump coal as the common fuel for commerical boilers and household furnaces. A buyer's market still exists and the waste material being placed on the pile continues to be high in fuel content. Due to the need to remain competitive, some machinery is introduced into the mine with the result that less preliminary cleaning and selection occurs during mining. Consequently, more rock, fines,

FIGURE I

COAL MARKETS 1917 – 1956



and other dilutant materials are handled at the preparation facility and more material having higher ash and sulfur content is discarded to the pile.

1925 - The demand for high quality metallurgical and intermediate quality power plant fuel continues to increase. Concentrating units are added to the screening and picking facility. The waste materials reaching the bank now contain less fuel values and are relatively higher in rock and ash constituents than during any previous period.

1929 - A major decline in the national economy begins and will continue for several years. In order to sell coal in a declining market, rigorous preparation is practiced, thereby maintaining competitiveness in a seriously oversupplied market. Although growth of the culm bank is limited, it becomes rich in fuel values.

1933 - The marketing situation for coal is unstable, but the trend appears to be upwards. Additional mechanization takes place in the mine with the result that fluctuating tonnages of high ash and high fuel value material are intermittantly being placed on the culm bank.

1940 - World War II is approaching, and increasing industrialization is creating a demand for all forms of energy. A seller's market exists and before it peaks in 1943, many existing culm banks will be spot loaded to recover pockets containing high fuel value materials. Material entering the culm bank is high in ash and moderate in sulfur, and because of spontaneous combustion and the mining of the richer pockets, the bank is becoming increasingly deficient in fuel value.

1945 - The advent of the diesel engine signals the beginning of the end of the railroad locomotive market. Also, other domestic markets are declining. Power stations and metallurgical coking ovens are the only growth markets for coal. More advanced cleaning and mining methods continue to be installed at the facility and a high ash, high sulfur and moderate fuel value material is placed on the culm bank.

1950 - The power station is modernized and pulverized fuel boilers are installed; moreover, increasing tonnages of clean, high quality metallurgical coal are produced and marketed. More mechanical equipment is introduced into the mine. At the plant, crushers are installed and the cleaning process is made more efficient. As a result of the demands for a high quality metallurgical product and the willingness of the power station to accept a lower cost middling quality fuel, the waste material being placed on the bank is very lean in fuel values and has a high ash and sulfur content.

1969 - Increasing safety legislation causes more water to be used in the mine and more diluent material to be removed. The ash or mineral content of the coal entering the cleaning plant continues to increase. Much more material enters the culm bank of high ash content and low to moderate fuel value. Older sections of the bank are being mined to recover previously discarded fuel values as a result of a seller's market.

1972 - A major change occurs as a result of air pollution control legislation. Coal is now being sold to utilities on the basis of sulfur content rather than on the traditional Btu value. In order to meet the new requirements, new and more costly methods of concentration are employed and large tonnages of medium ash, high sulfur and high fuel value material are being placed on the bank. In addition, more of the older portions of the pile are being mined for the moderate ash, moderate sulfur fuel values placed there previously.

While this history is of necessity brief and overly simplified and such a culm bank is purely hypothetical, it can serve to illustrate some of the complex inter-acting factors which determine the composition of the material present at any specific location within the pile. The most important conclusion to be drawn is that extensive sampling, both on the surface and at depth, will have to be performed before any accurate estimates of the reclaimable fuels present can be made.

CULM BANK OWNERSHIP

In the majority of cases, the ownership of a culm bank is a matter of public record; and the information is available through such agencies as EPA, ORSANCO, or the environmental resources departments of the specific states involved. If the culm banks are inactive or have been abandoned however, the ownership of the land involved may be unclear. In some cases, title may have passed to the municipality, whether state, county, township, or other political unit, in which the bank is sited due to tax claim action or bankruptcy proceedings. In other cases, title to the land may have been abandoned and no clear title exists. Also, it is possible that one person or company owns clear title to the land involved, but that another person or company holds the mineral rights to the culm bank and the land under it.

In addition to determining the ownership of the culm banks, potential leasors or buyers will have to determine the ownership of surrounding properties so that a right of free access may be obtained. This could be very difficult to acquire if the surrounding land is either residential or agricultural.

If active disposal sites are to be considered for fuel and mineral value reclamation, close cooperation and careful planning will be required between the existing owners and the reclamation group to ensure that recovery work does not interfere with the normal daily usage for which the site was intended. Areas of legal responsibility will also have to be carefully defined in any leasing or sales agreement. It is quite possible that active mining of the culm bank could lead to increased acid drainage and, if sufficient care is not taken, to combustion of all or a portion of the bank with its attendant air pollution problems of smoke and sulfur oxides emission.

In the case of inactive culm banks, responsibility for such problems as acid drainage and combustion may no longer rest with the original owner. However, sale or leasing of the bank may automatically assign responsibility to the new land user. A careful examination of transfer agreements and of the individual municipality's laws will be required before the responsibilities can be accurately determined.

Many of the culm banks in the Monongahela River Basin are being used as impoundment dams. The individual state water resources departments would have to be advised about any potential disruption of these sites; and suitable plans would have to be presented and approved concerning disposal and possible treatment of the impounded water before these sites could be altered or mined.

In addition to the factors discussed above, the degree or amount of difficulty to be encountered in the acquiring of title to properties being considered will also be determined to a large extent by the size of the potential reclamation project to be undertaken. For example, according to preliminary data obtained from Michael Baker, Jr., Inc., the Monongahela River Drainage Basin contains approximately 300 culm bank sites ranging in size from 1/2 acre to 350 acres. Broken down into size groupings, the data is as follows:

Greater than	100 acres	10 sites	2050 acres
Greater than	75 acres	15 sites	2410 acres
Greater than	50 acres	28 sites	3230 acres
Less than	50 acres	270 sites	3345 acres
	Total	298 sites	6575 acres

It can be seen from this data that 10 sites contain almost 1/3 of the acreage involved and probably 1/2 or more of the total tonnage. It is probable that many banks are even now being actively mined to recover their fuel values.

The names and addresses of the agencies which should be contacted first in order to determine the ownership of specific culm banks are as follows:

EPA - Division of Field Investigations
Cincinnati Center
5555 Ridge Avenue
Cincinnati, Ohio 45213

ORSANCO - Robert K. Horton, Chief Engineer
414 Walnut Street
Cincinnati, Ohio 45202

Pennsylvania Department of Environmental Resources
P. O. Box 2351
Harrisburg, Pennsylvania 17120

Maryland Department of Water Resources
State Office Building
Annapolis, Maryland 21401

West Virginia Department of Natural Resources
State Capitol
Charleston, West Virginia 25304

CULM BANK MAPPING

Mapping of culm bank sites could best be accomplished in three phases. First, the precise geographical location and areal extent of potential fuel reclamation sites could be found using aerial survey techniques combined with existing topographical maps to provide accurate longitude and latitude figures. Information concerning access roads, previous mining of the bank and current use of the bank, if any, could also be obtained in this manner. Such a study would probably require between three and nine months, dependent upon weather conditions and the extent of the survey.

The second phase, and probably the most difficult and most subject to possible error, would involve estimating the tonnages of material present at each site. Such estimates should include the results of both horizontal and vertical samples along with any bank history which could be obtained. After completion of the sampling program, the remainder of this phase would require approximately six months.

The third phase would consist of the actual preparation of the maps and the tabulation of the acquired data. The time required to complete this work would be largely dependent upon the number of sites being investigated, but would probably be between three and six months.

POTENTIAL ACID MINE DRAINAGE REDUCTION

The question of potential acid mine drainage (AMD) reduction is complex and involves several factors. Many of the refuse piles to be considered have stabilized and are not considered to be active acid drainage sites. However, if these potential fuel and mineral sources are mined, the possibility of new drainage being initiated will have to be carefully considered and planned for. An estimate based upon information obtained from the "Mine Drainage Report to the Conferees of the Enforcement Conference on the Monongahela River and its Tributaries" indicates that an average of 1.5 to 2.0 pounds of acid/acre/day could be produced along with 0.5 to 0.7 pounds of iron/acre/day. Because the possibility always exists that natural occurrences could initiate drainage through a previously non-acid producing culm bank, the potential amount of AMD reduction to be achieved by utilizing and removing the culm banks is sizable. Responsibility for any drainage which occurs during mining of the banks and afterwards will have to be determined and control methods will have to be selected before mining permits can be obtained.

POSSIBLE ACTION BY GOVERNMENT BODIES

Measures to encourage the reclamation of fuel and mineral values present in culm banks could be taken by the Appalachian Regional Commission and by the individual states. Among the possible measures, is the direct sponsorship and support of scientific research in such areas as:

1. The development of new equipment or methods for the combustion of low Btu coal wastes for the recovery of heat as well as for the reduction of the amount of waste material.
2. The development of better recovery methods to economically beneficiate the fuel, metal and sulfur components present in culm bank gob.
3. The development of remote mechanical and electronic sampling systems to permit deep and/or rapid sampling of the bank so that men and equipment are not required to travel on the surface. Culm banks occasionally have large and hidden internal voids and/or hot spots located beneath surfaces that appear to be substantial. Walking on such surfaces has resulted in a number of fatal accidents in the past.

The opportunity also exists for direct encouragement by individual states in the form of such incentives as tax benefits for reclaimed or recovered fuel and mineral values. In addition, public contracts for fuels could be prepared requiring a certain percentage of reclaimed fuel materials.

Also, land reclamation methods, such as those espoused by the National Coal Board in Great Britain, should be closely considered and used as a basis for further research. The ultimate aim of such a program would be the preparation and passage of laws to encourage reclamation plans where such methods would appear to offer a best solution to the problem of culm bank utilization.

Also, an important program of public education should be implemented on state, local, and national levels to emphasize the necessity of reclamation programs for the conservation of irreplacable natural resources and for the reduction of potential acid drainage and air pollution.

The greatest assistance to be offered could well be in the area of expediting the processing of the necessary permits and in the untangling of the red tape among the multitude of government agencies on all levels which would be involved in a culm bank reclamation program. Because environmental resources, air and water pollution control, and mining regulating agencies from all levels of government would be involved, it might be that the Appalachian Regional Commission could act as an arbitration board to define jurisdiction where more than one agency claims regulatory power in the same area.

AFFECTS UPON POWER PLANT OPERATIONS

It has long been known that materials with very low heating values can be burned. Coal refuse crushed to an easy to achieve one-quarter inch size and with as little as 3,000 to 3,500 Btu heating value has been burned in the Office of Coal Research pilot scale fluid-bed column designed and operated by Pope, Evans and Robbins.[1] On a dry basis, this refuse could contain approximately 65 to 70 percent ash. Coal waste with as little as 5,000 Btu heating value can be burned in specially designed, conventional boilers provided that the wastes are friable enough to permit economical grinding to a fine size.[2]

Boilers designed to burn coal waste must be equipped with oversize ash handling capability since approximately one-half or more than one-half of the coal wastes fed to the boiler would remain as ash and would therefore have to be continuously removed.

Combustion of coal wastes may be more influenced by volatile matter than by heating value. Hence, coal waste with 20 to 30 percent volatile matter may burn more readily than coal wastes of lower volatile content. The favorable influence on combustion of higher volatile matter is especially evident when burning fuel of equivalent heating value. Moreover, since both ash and moisture contribute to loss of heating value, it is preferable that much of the loss can be caused by ash instead of moisture. Hence, a low moisture and high ash feed is preferable to a high moisture and low ash feed. Fortunately, the high ash low moisture characteristic is predominant with fuel from refuse banks.

The direct burning of lean gob piles to produce power is well established from experience in France where anthracite waste banks have been used up as a source of fuel during the past twenty-five years.[3] Combustion was achieved using the Ignafluid boiler which burns coal refuse crushed to approximately 1/4-inch. Refuse with a dry ash content as high as 40 percent and heat content as low as 7,500 Btu's was found to provide a satisfactory fuel. Moreover, it is preferable that refuse fed to an Ignafluid installation should contain between 15 to 20 percent volatile matter, less than 5 percent sulfur and have ash with a fusion temperature ranging from 2,000 to 2,600° F.

Most present coal burning power plants operate with coal having fuel values ranging between 10,000 and 12,000 Btu per pound and with ash contents ranging up to approximately 30 percent. The refuse from most banks can be mixed directly with coal provided that the heating value and ash content of the mixed product meets the Btu design level of the boiler for which the fuel is intended.

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[1] Private communication with John Bishop, Pope, Evans and Robbins, Alexandria, Virginia.

[2] Private communication with Combustion Engineering Company, Windsor, Conn.

[3] Private communication with Paul A. Mulcey, Consulting Engineer, Dallas, Pennsylvania

POTENTIAL FOR THE ECONOMIC UTILIZATION OF CULM BANKS

Table 1 provides preliminary information about the size and composition of some randomly selected refuse banks in the Monongahela River Drainage Basin. Composition was determined from analysis of a refuse weight increment collected from each bank. From one to ten sub-increments were obtained from the edges of culm banks at depths ranging from 6 to 12 inches and these sub-increments were combined to form the weight increment which is identified with each bank. Because coarser particles tend to contain (1) higher ash, (2) require greater incremental weights to insure analytical representation and (3) can be readily removed by screening if the decision is made to commercially mine a refuse bank, culm particles of approximately 1 inch size and coarser were excluded from the increment. Test increments for banks of various sizes are reported in the table under composition on both an as received as well as a dry basis. Composition includes volatile matter, fixed carbon, ash, sulfur and Btu values. Because an extensive and long term sampling program would be required to establish the composition of all banks in the area, no conclusions are offered concerning the quality of the total deposit. Nevertheless, it is interesting to note that 8 of the 20 increments contain an as received volatile matter content of greater than 19 percent while 14 of the 20 increments contain as received heating values greater than 3,500 Btu with the result that nearly 75 percent of the bank increments meet at least one of these generally favorable characteristics. Had these increments been beneficiated, there is little doubt that considerably more than 75 percent would yield a product with 3,500 Btu and/or 19 percent volatile matter on an as received basis.

While the preceding estimates provide a measure of the relative number of bank increments that might be utilized in new or specially designed boilers, it is equally important to note the relative number of bank increments that might qualify for utilization as a fuel for the already commercially available Ignafluid process. Hence, 3 out of 20 bank increments would appear to readily qualify as an Ignafluid fuel and, with some beneficiation, as many as 14 out of 20 bank increments might be beneficiated to meet specifications. All of these observations suggest a favorable potential for the successful utilization of culm banks as a fuel for an existing and proven commercial boiler.

Finally, it would appear that the same raw and/or beneficiated 14 out of 20 bank increments could be used in blends with higher grade coal for utilization in existing power stations.

The preceding information strongly infers that a high percentage of coal refuse banks in the Monongahela drainage basin could be burned in new, modified or existing combustion processes to produce useful power with the simultaneous benefit of converting unsightly piles of refuse to greatly reduced quantities of more readily utilized ash.

TABLE 1

ESTIMATED SIZE AND COMPOSITION OF SOME RANDOMLY SELECTED COAL WASTE BANKS / LOCATED IN THE MONONGAHELA RIVER DRAINAGE BASIN

Size		Composition*- As Received Basis					
Cubic Yards	Acres	Moisture	Volatile Matter %	Fixed Carbon %	Ash %	Sulfur %	Btu
45,733,000	315	9.19	10.17	7.10	73.54	.31	1,589
8,219,000	102	16.29	16.20	19.21	48.30	2.02	3,943
7,644,000	39	7.61	12.80	9.50	70.09	.74	2,502
6,000,000	101	16.14	22.01	33.22	28.63	2.24	7,933
4,000,000	115	14.38	17.14	16.94	51.54	0.93	4,202
3,554,000	44	2.41	13.24	8.01	76.34	.69	2,225
3,000,000	32	19.50	16.16	7.18	57.16	2.23	2,315
2,800,000	44	8.28	15.97	21.15	54.60	.56	4,321
2,749,000	42	10.35	14.23	25.46	49.96	.81	4,802
2,000,000	29	9.08	26.38	41.08	23.46	1.14	9,611
1,400,000	23	9.60	25.34	23.51	41.55	7.17	6,475
1,299,000	27	23.62	16.38	9.50	50.50	2.59	2,467
871,000	6	11.29	14.89	21.18	52.64	0.83	4,547
700,000	5	9.30	19.41	23.64	47.65	0.78	5,828
600,000	21	13.80	19.30	24.31	42.59	1.34	5,756
200,000	5	9.18	15.98	30.21	44.63	.61	6,294
200,000	4	25.24	19.98	10.33	44.45	2.59	2,689
176,000	11	12.58	24.66	38.18	24.58	1.09	8,796
80,000	6	14.98	20.96	26.52	37.54	0.88	6,364
-	-	12.79	17.80	20.85	48.56	1.51	4,756

*Composition is based on analyses of some randomly selected increments of weight of refuse obtained from each bank.

(continued)

TABLE 1 (CONT'D)

ESTIMATED SIZE AND COMPOSITION OF SOME RANDOMLY SELECTED COAL WASTE BANKS / LOCATED IN THE MONONGAHELA RIVER DRAINAGE BASIN

Size		Composition - Dry Basis				
Cubic Yards	Acres	Volatile Matter %	Fixed Carbon %	Ash %	Sulfur %	Btu
45,733,000	315	11.20	7.82	80.98	.34	1,750
8,219,000	102	19.35	22.95	57.70	2.41	4,710
7,644,000	39	13.85	10.28	75.87	.80	2,708
6,000,000	101	26.25	39.61	34.14	2.67	9,460
4,000,000	115	20.02	19.78	60.20	1.09	4,908
3,554,000	44	13.57	8.21	78.22	.71	2,280
3,000,000	32	20.07	8.92	71.01	2.77	2,876
2,800,000	44	17.41	23.06	59.53	0.61	5,288
2,749,000	42	15.87	28.40	55.73	0.09	5,356
2,000,000	29	29.02	45.18	25.80	1.25	10,571
1,400,000	23	28.03	26.01	45.96	6.83	7,163
1,299,000	27	21.45	12.44	66.11	3.39	3,230
871,000	6	16.78	23.88	59.34	0.93	5,126
700,000	5	21.40	26.06	52.54	0.86	6,426
600,000	21	22.39	28.20	49.41	1.55	6,678
200,000	5	17.60	33.26	49.14	.67	6,930
200,000	4	26.73	13.82	59.45	3.46	3,597
176,000	11	28.21	43.67	28.12	1.25	10,062
80,000	6	24.66	31.19	44.15	1.03	7,485
-	-	20.41	23.91	55.68	1.73	5,453

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COAL MINE REFUSE AS LAND FILL AND EMBANKMENT MATERIAL

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COAL MINE REFUSE AS LAND FILL AND EMBANKMENT MATERIAL

INTRODUCTION

Coal mine refuse can be used as fill material in depression areas and for embankments if the projects are properly designed, constructed, and maintained. The utilization of coal mine refuse as fill material may not only reduce the initial cost of earthwork construction if the construction sites are within economic hauling distances of mine refuse piles, but should also increase land values after reclamation of the mining areas. Furthermore, the effective utilization of coal mine waste will certainly reduce air and water pollution and safety hazards, and improve the esthetic value of the land in mining areas.

During the past few years, the attitude towards the use of unburned coal mine refuse as fill material for civil engineering works has changed in Great Britain. This material was traditionally suspected of being liable to spontaneous combustion and was specifically excluded from most contracts and approved specifications. The success of the coal mining industry in controlling fires in refuse banks, and the construction of major engineering projects such as the Boulderhead Dam in Northumberland, England from coal measure shales, have led to a new approach. Advised by the Road Research Laboratory, the Ministry of Transport now permits the use of unburned refuse in highway embankment fills, etc., subject to consultation by the local authorities with the National Coal Board and the Road Research Laboratory as to the best method of placing and the best types of refuse to use.

Many unknown factors relating to the use of coal mine refuse as fill material still exist, such as: the degree of thermal and chemical changes of the material and its effect on the stability of the embankment; the effective and economic methods of controlling the pollution effluent and fire hazard; and the extent of the toxicity to vegetation in refuse banks. Despite all these uncertainties, the use of coal mine refuse as fill material will become more popular and the attitude of the public and the construction industry will change favorably in the United States as better techniques are developed and more knowledge is achieved through experience.

DESIGN CONSIDERATIONS

The following general considerations should be given when designing an embankment using coal mine waste:

1. The purpose and size of the structure, e.g., whether it is intended to be a highway embankment or a water retaining dike.

2. The stability of the foundations under the weight of the proposed embankment. On sloping ground, an investigation of its stability both under and downhill of the embankment will usually be necessary.

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3. Ground and surface water conditions at and around the proposed structure.

4. Mining subsidence which might form planes of weakness and paths for water seepage.

5. The bulk density and moisture content of the coal mine waste.

6. The shear strength and permeability of the material; which are dependent on its gradation, moisture content, density, and testing methods.

7. The extent to which the strength and permeability of the material are effected by the method of construction and the weather during the construction period. With some mine refuse, prolonged exposure to weathering or construction traffic may result in a plane of weakness, e.g., a plane of lower than normal shear strength or an impermeable plane along which seepage may be concentrated.

8. The extent to which strength properties of the material may change with time.

9. The practicability of zoning the embankment according to its physical characteristics. For example, the use of better quality material in the outer zones of an embankment may reduce surface erosion and permit steeper slopes.

10. The method of construction and type of supervision available for the day-to-day control of the civil engineering methods to ensure the proper construction of a stable embankment.

11. The potential risk to persons or property.

12. Statutory or contractual liabilities and obligations.

As in the design of every civil work, economic considerations as well as safety considerations should be given during the design and construction of embankments using coal mine refuse. However, because of the differences in nature between conventional earthwork material and coal mine refuse, the following physical and chemical properties should be carefully evaluated when using coal mine refuse in embankment construction:

1. Physical Changes

It has been observed that most types of fresh refuse change their mechanical properties on weathering and that, therefore, the strength of completed embankments may change if weathering is allowed. The physical actions which cause these changes include the disruptive effects of frost, water, temperature changes, and repeated wetting and drying. The principle minerals present in coal mine refuse are coal, silica, clays, and pyrite; together with ankerites, calcite, siderite, etc. These minerals are found in various grain sizes, bonded by various physical and chemical cements. The materials which are mainly coal bonded do not change their physical strength much on weathering, nor do the materials of high silica content such as the sandstones. However, siltstones and mudstones, particularly those which have a high clay content, may disintegrate sooner or later after exposure as a result of mining. It is obvious that refuse banks which contain any appreciable proportion of these disintegrating rocks may suffer appreciable changes of strength characteristics after construction if weathering is allowed.

2. Chemical Changes

Pyrite, often contained in refuse rock, oxidizes continuously while lying on the surface of a refuse bank. Oxidation of pyrite minerals within the body of an embankment or refuse bank is determined by the rate of penetration of air into the embankment or refuse bank and this depends upon the particle size distribution, the degree of compaction, and the degree of saturation with water. The products of pyrite oxidation are extremely acidic and are water soluble, but these acidic products may be neutralized rapidly by other alkaline minerals in the mine refuse. The effects of the neutralizing reactions are:

a. The pH value often remains near 7.0 and seldom falls below 3.0;

b. Iron oxides are precipitated, giving rise to ochreous staining of the mine waste;

c. Calcium sulphate crystals form inside fracture planes in the other rocks, and sodium sulphate crystals form as efflorescence on the surface of the mine waste bank in dry weather;

d. The mudstones in proximity to the pyrite may be converted to plastic clays by the action of sulphuric acid; and

e. Any water draining from the refuse bank may be contaminated with acidic or neutral salts.

These chemical changes may result in acid and sulphate attack on concrete, pollution of drainage water, and reduced fertility of the weathered refuse material.

The sulphate content of highly weathered unburned mine waste is normally sufficiently high to require special precautions in the design of concrete structures which may be in contact with the coal mine refuse material or with water from the refuse bank. This problem will be intensified if the refuse material has a low pH value.

Drainage water flowing from a refuse bank may contain concentrations up to several thousand parts per million (p.p.m.) of iron, aluminum, calcium, and magnesium sulphates derived from the action of sulphuric acid on carbonate minerals and clays. Concentrations of maganese salts, up to 10 and sometimes 100 p.p.m., may also be derived from the latter source. Many of the iron bearing waters are relatively clear when they emerge from the refuse bank, but rapidly become ochreous on exposure to the atmosphere. In some coal fields, water from refuse piles may contain sodium chloride in concentrations of a few hundred p.p.m. which has probably been derived from the refuse materials, but the concentration may rise to thousands of p.p.m. when tailings or slurry are lying on the refuse bank. Some of these waters may cause pollution if they are discharged directly into an inland water course or on to adjacent land.

Fresh discard, with a size range from medium sand to gravel or cobbles, is normally neutral or slightly alkaline in reaction; but as weathering proceeds, the material may become increasingly acidic. High acidity, and high local concentrations of salts of maganese, iron, and particularly aluminum, may increase the toxicity of the surface of the weathered refuse material and inhibit or prevent the growth of vegetation.

3. Fire Hazards

Coal mine refuse banks may be ignited accidentally by external agencies, such as by placing material with hot ashes or by lighting open fires or braziers. The most common cause of burning, however, is spontaneous combustion of carbonaceous materials, often aggravated by the presence of pyrite. This is an oxidation process in which the material combines with oxygen from the air with the evolution of heat. Oxidation usually proceeds very slowly at ambient temperatures but increases rapidly and progressively as the temperature rises. Neither oxidation, spontaneous combustion, nor burning will occur in the absence of air. For burning to occur with visible flame it is normally necessary for the material to be combustible, to reach its specific ignition temperature, and for sufficient oxygen to be supplied from the air.

When a refuse bank is fully burned or if such materials are used in constructing the embankment, the normal process of weathering is arrested because the structure of clay minerals has been changed to a more stable form and some vitrification may have taken place. When a refuse bank is partly burned, the situation is more complex, depending upon the temperature and the extent of burning. In mine refuse that is just warm, the normal processes of weathering will generally be accelerated. Where there is active heating in part of a bank, adjacent zones of unburned material may be subject to considerable chemical and physical changes depending on the temperature and the environment. Burning may lead to atmospheric and water pollution, and during the period of combustion acidic conditions will prevail in the bank.

COMPACTION OF COAL MINE REFUSE

In compacted coal mine refuse, the relationship between the moisture content (per cent dry weight) and the dry density has been found to behave quite similar to the Proctor curve of soil, i.e., a concave downward curve plot in the Cartesian coordinates with one wing (on the wet side) approximately parallel to the theoretical zero air void curve of the material. The dry density which can be achieved by compaction is influenced not only by moisture, which on the one hand is a necessary lubricant and on the other hand is responsible for creating voidage; but also by the particle size distribution of the refuse.

The benefits and effects of compacting coal mine refuse can be summarized as follows:

1. Compaction generally improves the shear strength of the material; but over-compaction of some materials may cause excessive crushing of the particles, and possible reduction of the strength of the material.
2. Compaction reduces the permeability of the material, which increases the rainfall run-off and reduces the quantity of seepage through the embankment. Increasing the amount of run-off will increase the risk of surface erosion. On the other hand, reducing the quantity of seepage through the embankment reduces the possibility of acid contamination of its effluent.
3. Compaction reduces the air voids and, therefore, lessons the possibility of spontaneous combustion. It will usually be more economical to compact the refuse material and prevent fires from starting than to spend time and money in putting them out.
4. Compaction helps to make the maximum use of the ground space available.
5. Compaction reduces the compressibility of the material.

In constructing embankments using coal mine waste, a compromise should be made between safety and economy. Therefore, the methods of placing and compacting coal mine refuse will depend on the circumstances of its use and the physical characteristics of the materials.

GENERAL RECOMMENDATIONS

In designing and constructing any load bearing fill or civil work using coal mine refuse, the principles and procedures used in the investigation, design, and construction of conventional earthwork structures should be used. In addition, the following are also recommended:

1. To reduce the potential of the physical disintegration of the material due to weathering after construction, the materials susceptible to weathering should be broken down as much as possible by construction equipment;

i.e., accelerate the weathering process by mechanical means during construction. The strength characteristics and other engineering properties to be used in the design should be based on the results obtained from the material after final compaction.

2. The measures which are taken to control stability of the coal mine refuse embankment will almost certainly eliminate the fire risk in all but the most noncohesive refuse, e.g., refuse from the anthracite mines. However, in order to further eliminate the chance of fire risk, the following precautions are recommended:

    a. Highly flammable material such as coal, oil logs, waste oil, containers of oil, and material containing cellulose, such as wood, straw, jute, paper cardboard, etc. should be avoided if possible.

    b. Boiler ashes, if used, should be quenched before placement on the embankment.

    c. Use of braziers should be prohibited or controlled during construction.

    d. The surface of the embankment should be sealed with noncombustible cohesive earth materials and properly compacted. For noncohesive refuse, the thickness of the sealing blanket should be increased.

3. Another problem which has now been recognized is delayed plant toxicity. It has been reported that a fly-ash treatment will eliminate or minimize the toxic elements in the refuse bank. However, until such a theory is well established, the sealing blanket on the surface of the embankment should be thick enough for planting and vegetation.

4. Infiltration of water into the coal mine refuse embankment by direct precipitation, storm run-off, stream flow, or from ponded water should be eliminated or minimized. If this can be done effectively, then the polluted effluent should be properly treated or neutralized by appropriate means before discharging to adjacent water courses.

5. The embankment should be properly zoned with various appropriate materials and compaction efforts to form the most economical and trouble free embankment practical.

6. Proper field inspection and/or instrumentation should be implemented after construction to detect possible instability, cracks, fire hazards, and pollution effects on the embankment.

The recommendations made here are only conceptual and qualitative in nature. Specific and detailed recommendations usually depend on the type of material and each individual project and can only be made after investigation and study of the engineering characteristics of the coal mine refuse to be used in each project.

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COAL MINE REFUSE AND FLY ASH AS A RAW MATERIAL FOR BRICKS, CEMENT BLOCKS, LIGHTWEIGHT AGGREGATE, MINERAL WOOL AND SUBSIDENCE AREA FILL

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COAL MINE REFUSE AND FLY ASH AS A RAW MATERIAL FOR BRICKS, CEMENT BLOCKS, LIGHTWEIGHT AGGREGATE, MINERAL WOOL AND SUBSIDENCE AREA FILL

BRICKS AND CEMENT BLOCKS FROM COAL MINE REFUSE AND FLY ASH

According to Spicer(1), residue from coal mines has been reported to be suitable for making bricks, with or without the addition of paste or other materials(2-9). In 1947, a Belgium patent described the addition of cement and water to pulverized coal shale to form a paste which is pressed in molds to make bricks(9). In 1958, a British Ceramic Society Transaction reported the use of coal washery tailings and other waste products in manufacturing building bricks(4). In 1963 and 1964, the utilization of dumped coal mining residues for bricks or cement was reported in a Hungarian(3) and a German patent(6). Clinker bricks and building bricks were made from coal mine shale with the addition of small amounts of sandstone and silt in Poland in 1968 and 1969(8). The waste consisted of kaolinite, minerals of the mica group, quartz, carbonates and organic matter(5, 8). In 1969, the utilization of coal dust slurries in cement blocks was investigated by the Franklin Institute Research Laboratories(2).

Glover(10) reported in 1971 that in Great Britain, a small quantity of coal mine refuse has been used directly for the manufacture of bricks for many years and a continued steady demand is forecast. However, most of the coal mine refuse in Great Britain contains carbonaceous minerals of too high a rank to make a good burnt brick. A few of the abandoned refuse banks have been reworked as sources of brick clays. An update by Maneval and Montgomery(64) estimates that profits before interest on brick manufacture from coal refuse was about one million dollars in Great Britain in 1972.

A new process, called "Tek-process" has been introduced by the Tekology Corporation of Palisades Park, New Jersey to manufacture bricks from inorganic solid wastes including coal mine tailings(11-15). This new process has been reported to be more economical and less time consuming than conventional brick making processes. The process does not emit the pollutants a conventional brick factory does(15). However, coal mine waste has to be burned at high temperature before it can be used as a raw material, therefore, it appears it would be uneconomical to use coal mine waste to manufacture bricks by the Tek-process.

Fly ash bricks and blocks have been reported in many foreign countries(16-23) and in the United States(16, 24-38). A process was developed by West Virginia University-Office of Coal Research (WVU-OCR) in 1964 for manufacture of fly ash bricks which met ASTM standards for clay bricks and manufacture was indicated to be economically feasible(24, 25, 28, 29, 31, 34-38). The pilot plant testing program resulted in the construction of a commercial plant, built by private funds utilizing the WVU-OCR fly ash brick process(65). The program has demonstrated that most, if not all, types of ash produced from American coals can be made into construction products

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meeting or exceeding ASTM standards for superior grade face brick. Face bricks having a 40 percent core area have been produced having the following advantages: 1) they are lightweight which lowers the haulage cost and structural steel requirements, and 2) there is a savings in cost due to the reduced amount of raw materials required(66).

The manufacture of lignite fly ash bricks has been reported by North Dakota State University(38-40, 42, 43) and West Virginia University(37, 38). Work has been reported on the manufacture of sand-fly ash(32, 33), flotation tailings-fly ash(43-46) and lime-slag-fly ash bricks(23).

Based on the success in Great Britain, and research at West Virginia University and Pennsylvania State University, it appears there is an economic potential for manufacture of bricks from coal refuse in the Monongahela River Basin. It should be pointed out though, that fly ash is in a very competitive position for this structural materials market.

LIGHTWEIGHT AGGREGATE FROM COAL MINE REFUSE AND FLY ASH

Refuse can be made into lightweight aggregate by heating it in a kiln or on a travelling grate. The escaping gases make bubbles in the viscous material which remain after cooling. This reduces the bulk density of the refuse. The rate of heating, temperature required to achieve incipient fusion, amount of gas escaping per particle, and the rate of cooling help to determine the quality of the expanded material. The particle size of the refuse fed to the kiln has an effect on all of these factors. The optimum size would have to be determined by tests and a complete analysis of costs. Tests were conducted by Pennsylvania State University in 1964 using a pelleted feed of 325 mesh material(48).

A lightweight aggregate was processed from bituminous refuse. This refuse was a carbonaceous shale that was converted into lightweight aggregate by pelletizing the refuse and burning off the carboniferous material on a chain-grate in a refractory-lined surface(49). A commercial development based upon the results of this study yielded a product which met ASTM specifications C130-42 for lightweight aggregates, and blocks made from this aggregate were of good color and light in weight(50). Structural compositions, including aggregate, produced by combining sludges from industrial acid waste sources with lime and pulverized coal fly ash were investigated by Minnick and the results are promising(51).

In 1971, Glover(10), reported that investigations have been conducted in Great Britain for at least 20 years on processes for production of lightweight aggregate, but no commercial plant has been constructed. Recently a National Coal Board-Minestone Executive advertisement in the November 7, 1974 issue of the New Civil Engineer, the publication of the British Institution of Civil Engineers, indicated a plant is under construction. This plant will be the first of many converting coal waste directly into construction materials. The initial plant will convert over half a million tons of coal waste annually into lightweight aggregate for the building industry to be used for construction of houses, offices and factories. The blocks made from this aggregate are called BRAG blocks. An import savings of about 3.5 million dollars annually will be achieved (See page IV-20).

The demand for lightweight aggregates is derived from concrete masonary units, structural concrete and to some extent precast structural units. Therefore, the ultimate use of coal refuse in the Monongahela River Basin area will depend upon a series of interrelated factors. These include:

1) The farthest distances concrete block can be competitively shipped.

2) The demand for concrete within a marketable distance from the Monongahela River Basin area.

3) The supply of other aggregates used in the manufacture of blocks.

4) The costs of other aggregates.

MINERAL WOOL FROM COAL MINE REFUSE AND FLY ASH

Mineral wool was discussed in a publication by the U. S. Bureau of Mines in 1929(52). The first investigation on the possible manufacture of mineral wool from anthracite refuse and anthracite ashes was in the late 1930's. Extensive research on mineral wool from anthracite refuse and anthracite ashes was performed at the Mellon Institute of Industrial Research by H. J. Rose and R. C. Johnson(53, 54). Their findings were reported in a paper presented at the Third Annual Anthracite Conference, Lehigh University, 1940. In a similar investigation in 1953, Rhode Island metaanthracite ash was used and proved to be a good wool source (55). Since 1966, West Virginia University has been investigating the feasibility of producing mineral wool from coal ash slags and fly ash(56, 57). The results indicate there is a definite potential in the Monongahela River Basin area for utilizing coal mine refuse and fly ash as a raw material in the mineral wool industry.

According to Charmbury and Chubb(67) preliminary tests made by a mineral wool producer, using current anthracite refuse as a raw material, resulted in wool with an undesirable brown color, but more importantly, the cupola could not operate in its normal temperature range without freezing. The need for a higher temperature was assigned to the alumina (Al_2O_3) content of the refuse. The material normally used by this manufacturer of mineral wool contains 12 to 13 percent alumina while the refuse contained 24 to 28 percent. The cupola would either have to be redesigned for operating at a higher temperature to use the higher alumina material, or other materials would have to be added.

COAL MINE REFUSE AND FLY ASH AS SUBSIDENCE AREA FILL

The use of coal mine refuse as fill material in areas depressed by subsidence is technically suitable and economically feasible provided the engineering properties of the material are properly investigated and the material is available within an economic haul distance of the fill area. The details regarding engineering properties and utilization of coal refuse as fill material have been described in other sections of the report.

The use of fly ash as fill material is in the early stages of development in thiscountry, however, the utilization of fly ash is quite popular in Great Britain where highway embankments have been constructed. The engineering properties of fly ash and its utilization as load bearing fill have been well documented(58-60, 63). Fly ash has also been used quite successfully, especially in the Pittsburgh area, to prevent mine subsidence(61). Bottom ash has been reported as a favorable aggregate for engineering purposes(62).

The stowing of anthracite refuse in abandoned mines to prevent surface subsidence has been practiced in the Anthracite Region since the 19th Century(68). The refuse for underground stowage, in most cases, has been crushed to 1/2 or 1/4 inch size, mixed with water, and flushed underground through a borehole. Several million tons of Anthracite refuse have been used for this purpose(69, 70).

Coal refuse for subsidence control has not been used to any extent in the Monongahela River Basin. The few subsidence control projects in this area have either utilized fly ash or a concrete aggregate to construct piers, caissons or to completely fill voids in a limited area where a structure was to be constructed(71). The successful utilization of coal refuse for mine subsidence control as practiced in the Anthracite Region should be applicable to the Monongahela River Basin.

ECONOMIC ASPECTS OF USING COAL REFUSE AND FLY ASH IN THE MANUFACTURE OF BUILDING MATERIALS IN THE MONONGAHELA RIVER BASIN

Discussions with about 20 different organizations and individuals in 1972 revealed there was little interest by manufacturers in utilizing coal mine refuse as a raw material for ceramic products. Cost estimates for setting up a small pilot plant to manufacture ceramic products from coal refuse range from $150,000 to $200,000. Without incentives manufacturers will not be willing to attempt the manufacture of ceramic products from mine refuse.

Japan is manufacturing ceramic products out of coal refuse(72). Burnt coal refuse rich in alumina is used as a material for refractory chamotte and refuse is intentionally burned for production of lightweight aggregate. When pulverized coal waste is compounded with about ten percent iron powder or other iron compounds burning produces a dense mass suitable for pottery. Heavy weight anti-abrasive floor tiles were successfully produced from coal waste combined with low grade pottery stone containing FeS as an impurity. Ornamental and protective tiles suitable for high rise construction have been made by adding foam producers such as glassy rocks to the above combination. The result is a lightweight substance with favorable strength and hardness; a ceramic glaze can be applied. The Research Development Corporation of Japan (an agency that licenses government patents) provided the funding for production facilities and product development is now in the sales promotion stage (1974).

Maneval(73) reported in 1974 that the Pittston Company, in Dante, Virginia, is producing lightweight aggregate from coal mine waste for a number of finished products. Approximately 570 tons of coal waste is converted daily into aggregate for a total production of 200,000 tons per year. The process involves firing the refuse at 2,000° F followed by cooling and crushing and screening for finished products, which include building blocks, structural concrete, and road building material.

Fly ash technology appears to be fairly well developed. Not only is fly ash used for ceramic products, but it is also used in putting out mine fires and for mine subsidence control. As a ceramic raw material it is first sintered and then combined to make lightweight aggregate blocks. Such an operation involves a capital investment of 1.5 to 2.0 million dollars. In addition to lightweight aggregate, fly ash can be combined with cement to produce concrete blocks at a saving of 10 to 20 percent for the operator of a concrete block plant.

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LABORATORY INVESTIGATION OF THE ENGINEERING PROPERTIES OF BITUMINOUS COAL MINE REFUSE

INTRODUCTION

Mine refuse has long been considered to be a significant source of air, water and visual pollution in coal mining regions. In some mining areas, coal refuse piles have occupied land which could otherwise be used for residential, industrial or recreational development. This is especially true in some of the larger, expanding urban areas. The effective utilization of mine refuse would not only help eliminate aesthetically unattractive coal refuse piles, but would result in a decrease in air and water pollution, a reduction in safety hazards, and the generation of "new" useful land at the removal sites.

Numerous studies have been made in the field of processing coal refuse for its heating value, and for the manufacture of building brick, lightweight aggregate, mineral wool and other useful materials. The time has come to focus attention on the study of coal refuse as a material for construction, particularly as a material for fill and embankment construction, because in this way, large volumes of coal refuse can be utilized.

The overall study being performed for the Appalachian Regional Commission has indicated that in the United States, there is an apparent lack of interest and very little knowledge relative to the engineering properties of coal mine refuse. For one thing, very little work has been accomplished in the United States regarding the engineering properties. For another, when coal refuse has been used on occasion as a fill or embankment material, the results have not always been successful, and sometimes the results have been disastrous, mainly because of this very lack of interest and understanding of its engineering properties. Knowledge of the engineering properties of coal refuse is urgently needed in the United States, not only from the standpoint of pollution abatement and resource recovery, but also from the standpoint of preventing future Buffalo Creek disasters.

It became apparent early in the overall study that federal, state and local agencies were reluctant to participate in environmental improvement projects where coal refuse would be utilized as the construction material. This reluctance was based in part on a knowledge of the combustible history of coal refuse, and in part, on an unwillingness to try something new in the United States even though it had been accomplished successfully in Europe.

Therefore, in order to encourage the utilization of coal refuse in the construction of future projects, an attempt was made with limited funds to investigate the engineering properties of bituminous coal refuse in the Monongahela River Basin. Samples were collected from both active and inactive refuse piles, and soil tests, modified for coal refuse properties, were performed. The soil tests included index properties, compaction and strength characteristics, moisture-density relationships and chemical properties. Despite limitations in the scope of study, promising and encouraging results were obtained.

SAMPLING AND TESTING

A. Sampling

For the purpose of determining the engineering properties of coal refuse, eleven (11) samples were collected from ten (10) different refuse bank sites. The location of refuse banks were chosen so that sampling locations were geographically scattered over the entire Monongahela River Basin in a random pattern. In order that sampling would be more representative, refuse banks were selected to include materials from two different coal seams with various degrees of weathering. An extensive and long term sampling and testing program would be required, if the variation in engineering properties of mine waste within a bank is to be determined. Consequently, four to ten sub-samples, depending upon the heterogeneity of the material, obtained from various locations in each refuse bank at depths ranging from 6 to 18 inches were combined to form an average sample for the refuse bank. After collection, the material to be sampled was sealed in a heavy duty plastic bag and stored in the laboratory maintained at constant room temperature.

Twenty (20) samples were also collected for composition analysis and the results of these tests are discussed in Section 6 of the report which covers the economic potential for utilization of coal refuse for its heating value. Some of the composition analysis test results have been used in connection with the engineering properties.

General information on the refuse banks sampled for material to perform engineering property tests is presented in Table 1.

B. Soil Index Properties

Tests for soil index properties include grain size distribution, liquid limit, plastic limit and specific gravity.

Grain size analysis is performed to determine the relative proportions of the different grain sizes which make up a given material. Actually, it is not possible to determine individual particle sizes, the test only brackets the particles within various gradation sizes. The grain size analysis test is universally used in the engineering classification of soils. The information obtained from grain size analysis is particularly useful for material which has grain sizes about the same as that of sand and silt. This data can be used to predict the range of permeability and capillarity of the material. It may also be used to determine the frost susceptibility of the material. A total of twelve (12) grain size distribution tests were performed. Nine (9) of the tests were performed on material as collected in the field and three (3) of the tests were on material used in compaction tests to determine the degree of mechanical degradation of the material after compaction. The results of grain size analysis tests are presented in Figures 1 through 5.

The liquid limit represents the boundary between liquid and plastic states of a material. It is also defined as the moisture content at which soil or mine refuse has such a small shear strength that it is on the verge of becoming a viscous fluid. The plastic limit represents the boundary between the plastic and semisolid states of a material and is also defined as the moisture content at which the material begins to crumble when rolled into threads of a specified diameter. The difference between the liquid limit and plastic limit is called the plasticity index. The limits are very useful especially for fine-grained material, i.e., material predominantely composed of particles finer than the No. 200 sieve size (0.0029 inches). They furnish an excellent basis for the classification and identification of such materials. The liquid and plastic limits are used to predict structural properties, such as permeability, compressibility and strength of a material. Liquid and plastic limit tests were performed on nine (9) samples and the results are presented in Table 2.

The specific gravity of coal refuse is needed for determining the air void content and degree of saturation of the material. It is also used in the computations for most of the laboratory tests, especially for relating weight to volume. Because of a distinct difference in specific gravity between bituminous coal and common soil minerals, specific gravity may also be used to estimate the carbon content of coal refuse.* Eleven (11) specific gravity tests were performed and the results are presented in Table 2.

All index properties were tested using Standard ASTM (American Society for Testing and Materials) methods modified for coal mine refuse in accordance with British Standards (Application of British Standard 1377: 1967 to the Testing of Colliery Spoil).[1,2,3]

C. Moisture-Density Relationship (or Compaction) Test

Compaction of mine refuse is required in order to increase shear strength and to decrease compressibility, permeability and the combustion potential of the material. Although the fundamentals of compaction are not completely understood, it is known that water plays an important part. Water serves as a lubricant, therefore, the addition of a small amount of water to dry mine refuse aids the compaction process. Up to a certain point, additional water displaces air in the voids, but after a relatively high degree of saturation is reached, water begins to occupy space which could be filled with solid particles and the amount of entrapped air remains essentially constant. There is, therefore, an optimum water content for a given coal refuse material and compaction process which will give a maximum dry weight of material per unit volume.

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*The specific gravity of bituminous coal is about 1.4 whereas common soil minerals have specific gravities in the range of 2.6 to 2.8.

The purpose of a laboratory compaction test is to determine the proper amount of water to be added when compacting coal refuse in the field and the resulting degree of denseness which can be expected from compaction at this optimum water content. To accomplish this purpose, the laboratory test must give a degree of compaction comparable to that obtained by field compaction methods. ASTM standard compaction tests use a 4 or 6 inch diameter mold with a 5 inch depth and are based on the material passing the No. 4 (0.187 inches) or 3/4 inch sieve. To compensate for coarse material in a sample, as in the original field condition, the standard methods recommended replacement of the portion of material passing the 2 inch sieve and retained on the 3/4 inch sieve with an equal amount by weight of coarse material passing a 3/4 inch sieve but retained on a No. 4 sieve.

A method of using a mold 12 inches in diameter by 12 inches deep has been developed by the U. S. Army Corps of Engineers(6) for samples containing more than 10% of material by weight larger than the 3/4 inch sieve. However, in using this method, a much larger quantity of material is needed for each compaction test.

Six (6) sets of compaction tests were performed using a 4 inch mold. Four (4) of the tests were performed on material passing the No. 4 sieve and two (2) were run on material passing the 3/4 inch sieve. ASTM standard methods were used and fresh material, i.e., not previously compacted, was used for each point of the compaction tests. When more than one set of compaction tests were run on the same material, and the material had to be reused, separate material, previously compacted only once, was still used for each point. The compaction test results are presented in Table 2 and Figures 6 through 9.

D. Strength Test

The triaxial compression and direct shear tests normally used to determine strength characteristics of foundation and embankment soils can also be used to determine the strength properties of coal mine refuse. In performing laboratory shear strength tests, the test conditions should always simulate as close as possible expected insitu soil conditions. Three standard test conditions are available. They are: 1) Unconsolidated-Undrained or quick (Q) tests in which the water content is kept constant during the test; 2) Consolidated-Undrained (R) tests in which consolidation or swelling is allowed under initial stress conditions, but the water content is kept constant during application of shearing stresses; and 3) Consolidated-Drained (S) tests in which full consolidation or swelling is permitted under initial stress condions and also for each increment of load during shear. These three test conditions normally provide limiting shear strength values corresponding to various prototype loading and drainage conditions.

The Q test conditions approximate end-of-construction shear strengths of embankments consisting of relatively impervious material or of impervious zones of zoned embankments. This test is also applicable to impervious foundation layers in which the consolidation rate is slow compared to the fill placement rate. The R test applies to conditions in which impervious or semi-impervious soils that have been fully consolidated under one set of stresses and are subject to a stress change without time for consolidation to take place. Results of S tests are applicable to: 1) free-draining materials in which pore pressures do not develop, 2) evaluating shear strengths of embankment or foundation materials that tend to increase in volume during shear and in which excess pore water pressures due to incomplete consolidation have been measured or can be estimated, and 3) evaluating field shear strengths where pore water pressures have been measured and slope failures have occurred or are impending.

Four (4) Unconfined Compression tests (the Q test without confining pressure) were performed on the coal slurry sample obtained from Bank No. 4A. Figure 7A presents the test results and each test was performed on a separate portion of the sample material, representing different degrees of compaction and molding moisture content. Standard Q tests were performed on material obtained from refuse banks No. 74 and No. 197. The material for the Q test was compacted using the Standard Proctor Method to near optimum moisture content and maximum dry density. The test results for this series of tests are presented in Figures 8A, 8B, 9A and 9B.

The triaxial compression apparatus used to perform the tests was limited to small diameter test samples. Therefore, only material passing the No. 4 sieve size could be tested for valid results. This study is limited in scope and only Q tests, the least expensive of the strength tests, were performed. A more comprehensive testing program is planned using triaxial compression apparatus capable of testing larger diameter samples. This apparatus is needed because the particle size distribution of coal waste samples tends toward the coarser sizes. The more sophisticated strength tests such as the R and S tests will also be performed.

E. Chemical Tests

Chemical tests were performed on coal refuse samples to determine pH, percent of soluble sulfate, and weight of soluble iron per unit weight of material. The hot phenolphthalein acidities of the water used in extracting soluble sulfates were also determined.

The pH value measures the hydrogen ion concentration of the aqueous portion of the coal refuse and was determined in accordance with British Standard 1377: 1967, Test 10A(2) as modified in Application of British Standard 1377: 1967 to the Testing of Colliery Spoil(3). Basically a portion of the sample is air dryed, crushed, and then distilled water is added to the sample. The pH of the resultant slurry is determined electrometrically with a combination pH electrode. The pH values of nine (9) samples are presented in Table 3 along with other chemical test results.

The soluble sulfate content was also measured in accordance with British Standards, except that sulfate leached from the sample was determined turbidimetrically rather than gravimetrically. This test measures the amount of soluble sulfates present in the sample which are mostly in the form of calcium, magnesium, iron and aluminum sulfates.

Tests were performed to determine the amount of soluble iron present and the hot phenolphthalein acidity of the water needed to extract soluble sulfates. These tests give an indication of the pollution potential of coal refuse. The soluble iron content of coal refuse is significant because if it is washed into a stream it can result in acid mine drainage. Acid conditions will occur when the iron precipitates as ferric hydroxide, removing hydroxal ions from solution, thus increasing the hydrogen ion concentration which lowers the pH of the stream. The hot total acidity test(9) measures the amount of alkali expressed in equivalent mg/l (milligrams per liter) of calcium carbonate needed to neutralize the water. High total acidities are due mainly to the presence of dissolved iron and aluminum sulfate, the most important constituents of mine drainage.

DISCUSSION OF TEST RESULTS

A. Soil Index Properties

The test results persented in Table 2 show the specific gravity ranged from 1.45 to 2.30 and the Atterberg limits, the combination of liquid limit and plastic index, were for non-plastic material. The grain size analysis data presented in Figures 1 through 5 indicates that, except for coal slurry material, coal refuse materials are well graded, i.e., poorly sorted, even after compaction.

The specific gravity test results were used to calculate the porosity and percent of air void of the coal refuse as shown in the plot of each compaction test, Figures 6 through 9. Specific gravities were also used in correlation with percent of ash content, percent of volatile matter plus fixed carbon, percent of fixed carbon and Btu content. Calculations of statistical data, determination of least square regression line and its coefficients of correlation, were performed with an IBM-360-65K computer. The coefficients of correlation shown in Figures 10 through 14 indicate the correlation between specific gravity and composition of material or Btu content can be accepted with a high degree of confidence.

The results of the correlation analysis clearly indicate composition and Btu content of coal mine refuse can be estimated from a very simple specific gravity test. If sufficient tests are performed to establish this type of relationship or correlation for a coal refuse pile, the information would be very useful in a coal refuse utilization program.

B. Compaction and Strength Characteristics

Based on the Atterberg Limit test results (Table 2) and the grain size distribution curves (Figure 4), the coal refuse samples were all non-plastic, cohesionless materials. The compaction test used in the study generally produces a well defined moisture-density relationship for cohesive soil, but not necessarily for noncohesive material. However, as indicated in Figures 6 through 9, the tests produced results showing good moisture-density relationships. The test results show, that with a constant compactive effort, air voids decrease with increasing moisture content up to a certain moisture content; thereafter, a further increase in moisture content does not decrease the percent of air void. The moisture content at which the percent of air void remains relatively constant is called the optimum moisture content. The percent of air void lines shown in Figures 6 through 9 were established using the specific gravity of each sample.

The coal refuse material is crushed upon compaction, therefore, even for the same sample, the specific gravity will vary with the particles size of the material. Accordingly, it is believed that in determining the percent of air void at each degree of compaction, the moisture-density relationship curve is more realistic if fresh material is used for each degree of compactive effort.

Many factors significantly affect laboratory compaction test results(10). These factors include: 1) size and shape of the mold, 2) type and amount of compactive effort, 3) methods used in processing and compacting the soil, 4) method of determining the moisture content, 5) soil temperature, and 6) soil type. With all factors remaining constant, the maximum dry density obtained when using reused or "compacted" material is generally higher than the maximum dry density obtained when fresh material is used, i.e., material that has not been previously compacted. It has been reported(10, 12), that with other factors remaining constant, the maximum dry density in general increases with an increase in percent of coarse material (material coarser than No. 4 sieve size) as long as the percent of coarse material is less than a certain limit. These conclusions based on soil mechanics theory and practice appear also to be valid for testing coal refuse.

Curve 1 presented in Figure 6 represents a sample with 20 percent coarse material after compaction (See Figure 5) and shows a higher maximum dry density than Curve 2 which represents a sample with no coarse material. In these two tests, the increase in maximum dry density from testing reused material was apparently offset by a much larger increase in maximum dry density resulting from the presence of coarse material in the first sample. However, in Figure 8 the sample consisting of reused material and no coarse fraction had a higher maximum dry density (Curve 2) than the sample containing coarse material (Curve 1).

It is obvious coarse material had a greater influence on maximum dry density test results for samples from Refuse Bank No. 4 (Figure 6). Conversely, the reused material containing no coarse fraction greatly influenced maximum dry density test results for samples from Refuse Bank No. 74 (Figure 8). The explanation for these test results, as evidenced by Figure 5, appears to be: 1) the material from Refuse Bank No. 4 after compaction contained a higher percentage of coarse material, and 2) the material from Refuse Bank No. 74 was subject to greater breakability during compaction which was more pronounced during compaction of the "reused" material. The compaction test results also indicated maximum dry density decreases as the amount of fixed carbon and volatile matter increases or as the specific gravity of the material decreases.

A preparation plant slurry, sample 4A, and coal refuse samples from Bank No. 74 and No. 197 were tested for their strength characteristics. Figure 7A illustrates the variation of unconfined compressive strengths with different molding moisture content and dry density. It is interesting, as is often observed in most cohesive soil, that the maximum strength occurs at a molding moisture content of approximately 4 percent drier than optimum moisture content. Figures 8 and 9 present the "undrained" strength parameters of samples from refuse banks No. 74 and No. 197. Because of the small volume of bulk sample collected in the field, the strength tests were performed using material from the compaction tests. It is believed the strength test results would have been different, possibly higher, if the tests were performed on "fresh" material instead of the "reused" or previously compacted material. Additional strength tests are needed on coal refuse material before any definite conclusion can be reached. However, the test results obtained using previously compacted material compare favorably with strength test results of most natural "undisturbed" soils and remolded soils with the same compactive effort.

The type of strength test selected for the study of coal mine refuse was not intended to simulate or predict the actual or design strengths to be expected in the field. The purpose of the tests was to demonstrate probable strength characteristics of coal mine refuse and to indicate the promising aspect of using this material in construction.

C. Chemical Properties

Table 3 indicates most of the samples tested have a low pH and would therefore cause corrosion and deterioration of unprotected metals and concrete if they were exposed to the coal mine refuse. To prevent the corrosive action of acid waters on drainage structures, several states have adopted guidelines for general highway construction. For example the Pennsylvania Department of Transportation in their "Suggested Guides for Corrosion Protection Based on the pH Values of Water" specify the following materials for culvert pipes or underdrains:

pH - 3.5 or less - Corrugated Stainless Steel, Vitrified Clay, Coal Tar-Epoxy Lined R.C.C., or Vitrified Clay Lined R.C.C. Pipe

pH - 3.5 to 5 - Corrugated Galvanized Metal or Corrugated Aluminum Alloy Pipe (Fully Asphalt Coated)

pH - 5 to 8 - Corrugated Galvanized Metal or Corrugated Aluminum Alloy Pipe (No Coating)

pH - 8 and above - Corrugated Galvanized Metal or Corrugated Aluminum Alloy Pipe (Fully Asphalt Coated)

Corrosion resistant drainage pipes are also considered where high sulfate concentrations exist.

Concrete structures in contact with low pH soils or water should have protective resin or bituminous coatings applied. Where less severe pH conditions exist, surface sealing compounds such as water glass (sodium silicate solution) or drying oils may be used satisfactorily. In evaluating the corrosiveness of low pH soils or water, consideration must be given to the fact that conditions may change. For example, samples from refuse banks No. 4A and No. 96 when collected had a pH of 7.2 and 8.3 respectively. However, if these materials are not compacted, it is possible the pH may become much lower in time because pyrite and/or marcasite if present in the material will undergo oxidation. Proper compaction of coal refuse from these banks should prevent a significant lowering of pH.

The soluble sulfate content (as $SO_4^=$) of samples tested ranged from 0.015 to 2.78 percent. Because soluble sulfate content is primarily the result of oxidation of iron sulfide minerals, the amount of sulfate present is usually dependent on the degree of weathering and initial sulfide mineral content of the coal refuse material. The amount of sulfate present is of important engineering significance since high sulfates result in electrochemical corrosion of metals and deterioration of concrete. Sulfate bearing waters react with concrete to form insoluble reaction products of greater volume resulting in expansion and disruption. The following Table(11) shows the relative degree of attack on concrete by soils and water containing various concentrations of sulfate.

Relative Degree of Attack by Sulfates	Water Soluble Sulfate as $SO_4^=$ in Soil Samples (%)	Sulfate as $SO_4^=$ in Water Samples (mg/l)
Negligible	0.00 - 0.10	0 - 150
Positive[1]	0.10 - 0.20	150 - 1000
Considerable[2]	0.20 - 0.50	1000 - 2000
Severe[2]	Over 0.50	Over 2000

Notes: 1 - Use ASTM Type II cement
2 - Use ASTM Type V cement

Six (6) of the mine refuse samples indicated the soluble sulfate content was in excess of 0.20 percent. Concrete placed in contact or near such refuse should be made with sulfate resistant ASTM Type V Portland cement, preferably with a relatively low water cement ratio. Low calcium, Modified ASTM Type II, cement may be used in some cases where moderate sulfate action is anticipated. Although the coal refuse used in construction may contain a relatively small amount of soluble sulfate, the amount may increase in time because of weathering of the material.

Hot total phenolphthalein acidities and total filterable iron concentrations of portions of the water used in extracting soluble sulfates were determined to evaluate possible pollution problems that could occur during construction of fills and embankments using coal refuse. The samples from coal refuse banks No. 240 and No. 290 indicated acidities could be relatively high. If material from these refuse banks were used, precautions should be taken during construction to prevent contact with surface waters which could leach the highly soluble acid forming iron and aluminum salts.

CONCLUSIONS

Based on the laboratory test results obtained in this study, the following conclusions relative to the use of coal refuse in construction can be made:

1. Coal refuse is non-plastic and a better grade fill material than many accepted natural soil materials.

2. The specific gravity of coal refuse is a very useful criteria. It is not only useful for determining engineering properties, but can be used for estimating the composition of bituminous coal refuse.

3. The Proctor test which defines the relationship between moisture content and dry density of soils can be used to control field compaction of coal refuse.

4. The air void content of coal refuse can be greatly reduced thereby decreasing permeability and the potential for combustion even if the material is compacted only to the maximum dry density determined by the Standard Proctor test.

5. The strength test results indicate coal refuse provides adequate strength if the material is properly compacted.

6. Most of the coal refuse samples tested indicated pH values were low and soluble sulfate contents were relatively high. Therefore, design considerations should include water pollution control and provisions for protection of concrete and metal structures.

It is apparent better sampling techniques and additional testing is necessary to establish specific engineering criteria for the use of bituminous coal refuse in construction. It is also recognized the study of engineering properties of bituminous coal refuse should include compressibility, permeability and the combustion potential of the material. Despite the limitations of this study, the conclusions reached do indicate bituminous coal refuse can be used successfully in engineering construction. Because the possibilities of utilizing coal refuse in construction are very real, public attitudes must change if this material is to be considered a resource rather than a source of air, water and visual pollution resulting from the mining of bituminous coal, a valuable resource which is becoming increasingly important as the energy crisis becomes worse.

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10. Johnson, A. W., and Sallberg, J. R., 1962, Factors Influencing Compaction Test Results, Highway Research Bulletin 319, Washington, D. C.

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TABLE 1

GENERAL INFORMATION ON THE REFUSE BANKS SAMPLED

Spoil Bank Number	Lab. Sample Number	Date Sampled	Location	Coal Seam	Status	Age	Remarks
4	72-196	8/9/72	Plum-Renton Allegheny Co., Pennsylvania	Freeport	Active	Relatively Fresh	
4A	72-195	8/9/72	Plum-Renton Allegheny Co., Pennsylvania	Freeport	Active	Fresh	Mine slurry sample from lagoon.
14	72-198	8/9/72	Lawrence Washington Co., Pennsylvania	Pittsburgh	Inactive	Weathered	
74	72-197	8/10/72	Wyano Westmoreland Co., Pennsylvania	Pittsburgh	Inactive	Weathered	Mine opened 1896, closed 1943 - partially burned.
81	72-211	8/10/72	Mt. Pleasant Westmoreland Co., Pennsylvania	Pittsburgh	Inactive	Weathered	
96	72-212	8/14/72	Ellsworth Westmoreland Co., Pennsylvania	Pittsburgh	Active	Fresh	Material only 2 days old when sampled.
197	72-199	8/15/72	Cassville Monongahela Co., West Virginia	Pittsburgh	Inactive	Weathered	
240	72-213	8/9/72	Owings Harrison Co., West Virginia	Pittsburgh	Inactive	Weathered	
290	72-200	8/10/72	Century Barbour Co., West Virginia	Pittsburgh	Inactive	Weathered	
244	72-233	8/14/72	Dola Harrison Co., West Virginia	Pittsburgh	Active	Fresh	
196	72-232	8/15/72	Cassville Monongahela Co., West Virginia	Pittsburgh	Inactive	Weathered	

TABLE 2

SUMMARY OF SPECIFIC GRAVITY, ATTERBERG LIMITS AND PROCTOR TESTS

Spoil Bank No.	Lab. No.	Material Description	Specific Gravity	Atterberg Limits		Compaction(4)	
				Liquid Limit	Plastic Index	MDD (pcf)	OMC (%)
4	72-196	Fine Coal w/ pcs. of coal and carbonaceous shale	1.54(1)	NO(2)	NP(3)	73.2	15.9
4A	72-195	Fine coal slurry	1.45	NO	NP	64.8	20.0
14	72-198	Carbonaceous shale w/some coal	2.04	NO	NP	--	--
74	72-197	Gray brown clayey silt, w/much carbonaceous shale and some coal	2.13	NO	NP	102.7	12.2
81	72-211	Carbonaceous shale w/some coal and some sandy silt	2.07	NO	NP	--	--
96	72-212	Carbonaceous shale and gray silty clay with some coal	2.27	NO	NP	--	--
197	72-199	Carbonaceous shale w/much coal - a trace of gypsum crystals present	1.59	NO	NP	75.1	16.3
240	72-213	Mixture of underclay, carbonaceous shale, sandstone, reddog and coal. Gypsum crystals present.	2.29	NO	NP	--	--
290	72-200	Mixture of weathered reddog, underclay, cinders and some pieces of coal	2.30	NO	NP	--	--
244	72-233	Carbonaceous shale and coal w/some sandstone and trace of cinders	1.96	--	--	--	--
196	72-232	Carbonaceous shale and coal w/some siltstone fragments	1.83	--	--	--	--

Notes:
(1) All specific gravity tests were performed for the samples passing a No. 10 sieve except for the sample from Bank No. 4 which was **tested on the sample finer than a No. 4 sieve and the sample from Bank No. 17 which was tested on the sample finer than a No. 40 sieve.**
(2) NO = Non-Obtainable
(3) NP = Non-Plastic
(4) Proctors performed by ASTM D698-70 - Method A

TABLE 3

SUMMARY OF CHEMICAL ANALYSIS

Sample Location Number	pH(1)	% Soluble Sulfate(2) (as SO3)	% Soluble Sulfate (as $SO_4^{=}$)	mg/l Sulfate ($SO_4^{=}$) in 150 ml of water used to wash 10gm sample	Total Filterable Iron(4) (mg/l) of water used to wash sample	mg Soluble Iron per Kg of Spoil	Hot Total "P" Acidity(3) (equiv. mg/l $CaCO_3$) of water used to wash sample
4	5.3	0.33	0.39	260.	0.11	1.7	2.5
4A	7.2	0.44	0.53	355.	0.06	0.9	-1.0
14	3.3	0.23	0.28	185.	0.33	5.0	23.
74	3.5	0.014	0.017	11.	0.40	6.0	5.0
81	3.8	0.013	0.015	10.	0.02	0.3	10.0
96	8.3	0.033	0.039	26.	--	--	-1.0
197	4.6	0.56	0.68	420.	0.18	2.7	28.
240	2.8	2.31	2.78	1850.	21.0	315.	360.
290	3.0	2.25	2.70	1800.	6.6	99.	125.

Notes: (1) pH determined electrometrically according to B.S. 1377: 1967, Test 10A, as modified by Application of British Standard 1377: 1967 to the Testing of Colliery Spoil.

(2) % Soluble Sulfate determined according to B.S. 1377: 1967, Test 9, except soluble sulfate leached from sample was determined turbidimetrically rather than gravimetrically.

(3) Hot Total Phenolphlhalein Acidity was measured following procedures as found in "Standard Methods for the Examination of Water and Wastewater", Twelfth Edition.

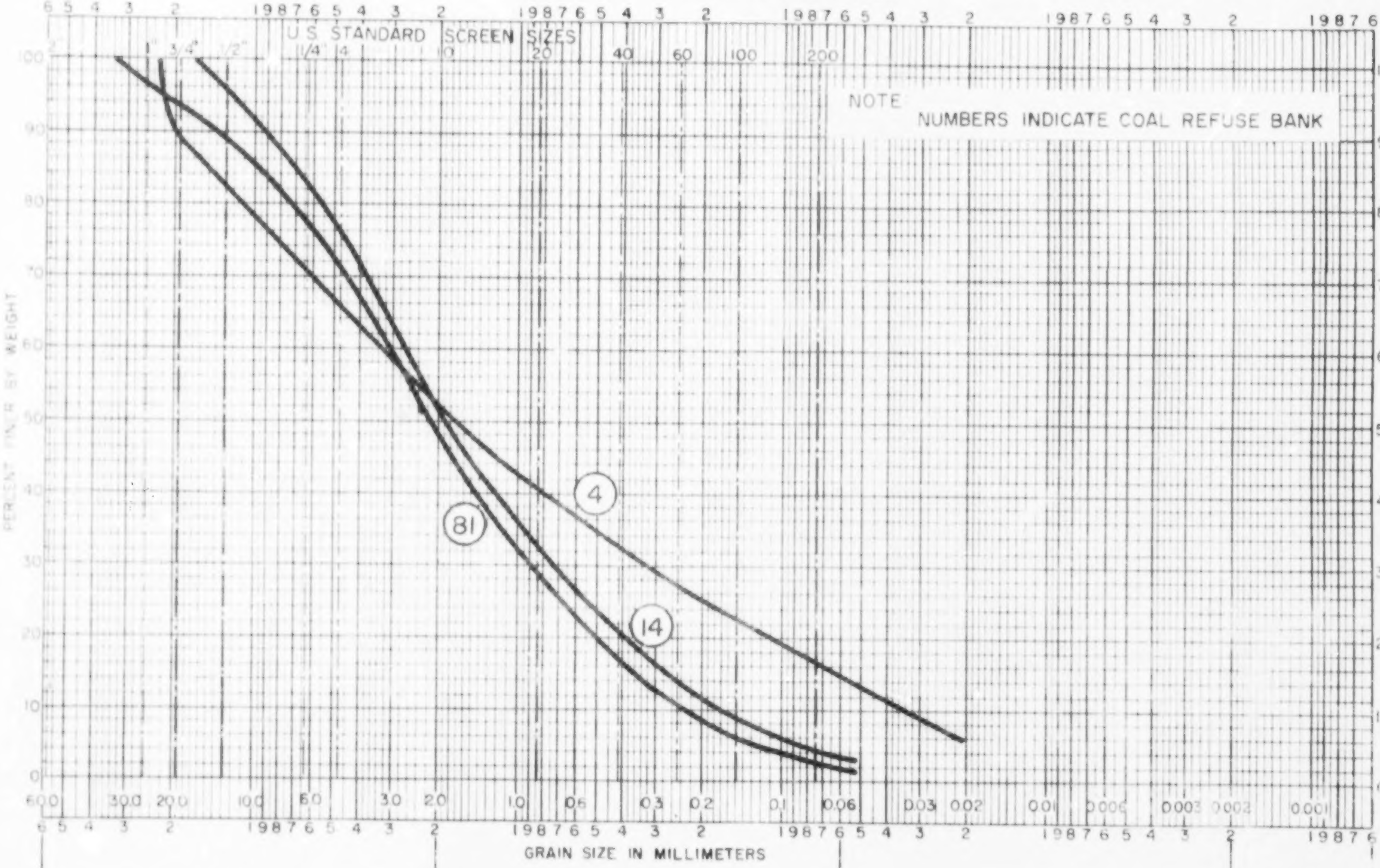
(4) Total Filterable Iron was measured using "Ferro-Ver" reagent supplied by the Hach Chemical Company after filtration through Whatman #42 filter paper.

TABLE 4

COMPOSITION OF BITUMINOUS COAL REFUSE - DRY BASIS

Spoil Bank No.	Lab. No.	Volatile Matter %	Fixed Carbon %	Ash, %	Sulfur, %	Btu.
4	72-196	26.25	39.61	34.14	2.67	9,460
14	72-198	15.87	28.40	55.73	0.09	5,356
74	72-197	17.41	23.06	59.53	0.61	5,288
81	72-211	16.78	23.88	59.34	0.93	5,126
96	72-212	13.57	8.21	78.22	0.71	2,280
197	72-199	28.21	43.67	28.12	1.25	10,062
240	72-213	20.07	8.92	71.01	2.77	2,876
290	72-200	26.73	13.82	59.45	3.46	3,597
244	72-233	28.03	26.01	45.96	6.83	7,163
196	72-232	22.39	28.20	49.41	1.55	6,678

MONONGAHELA RIVER BASIN MINE REFUSE STUDY
FIGURE I – GRADATION CURVES



GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES ___			% SAND SIZES ___			% SILT SIZES ___			% CLAY SIZES ___

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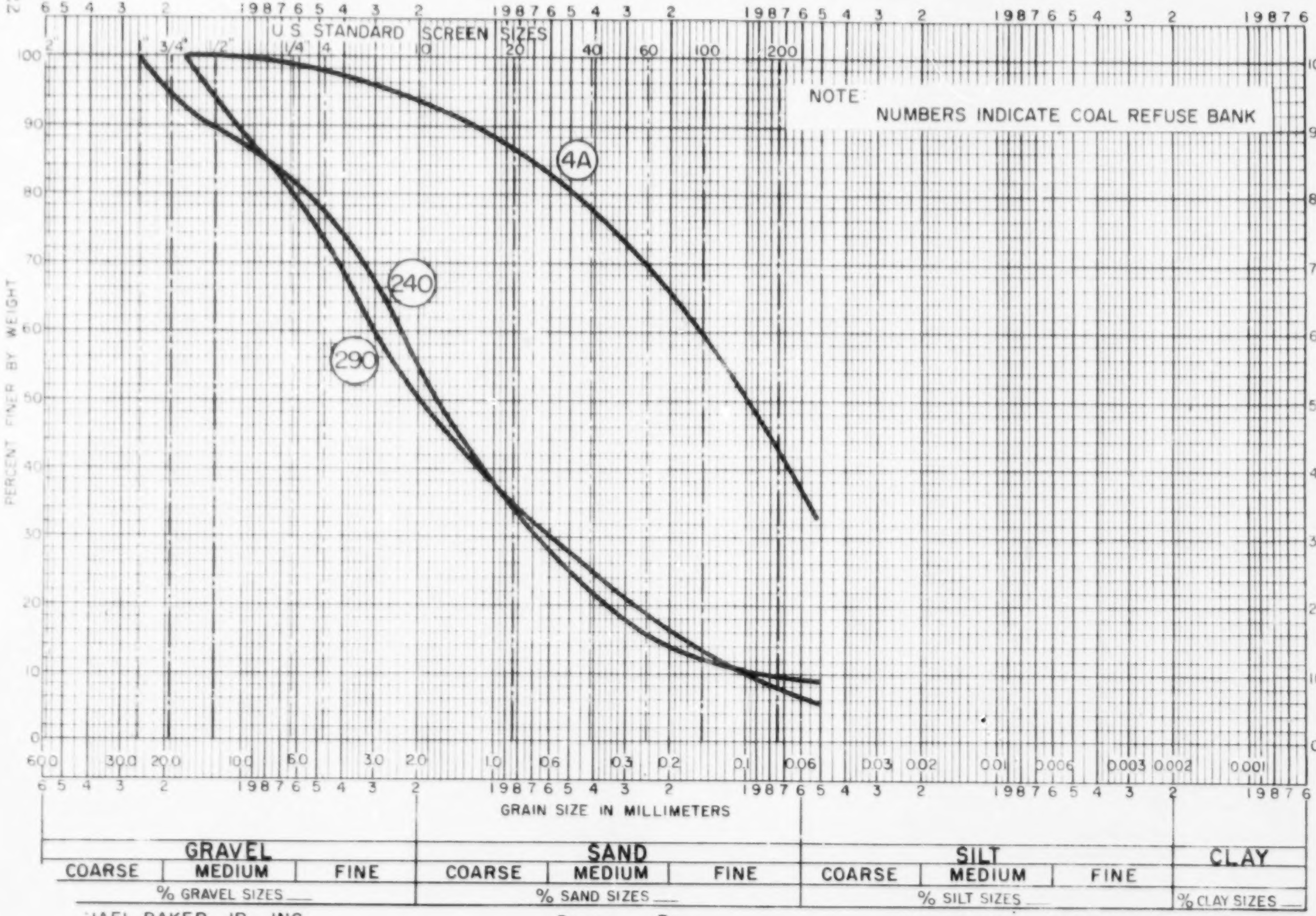
MONONGAHELA RIVER BASIN MINE REFUSE STUDY

FIGURE 2—GRADATION CURVES (Cont'd.)



NOTE:
NUMBERS INDICATE COAL REFUSE BANK

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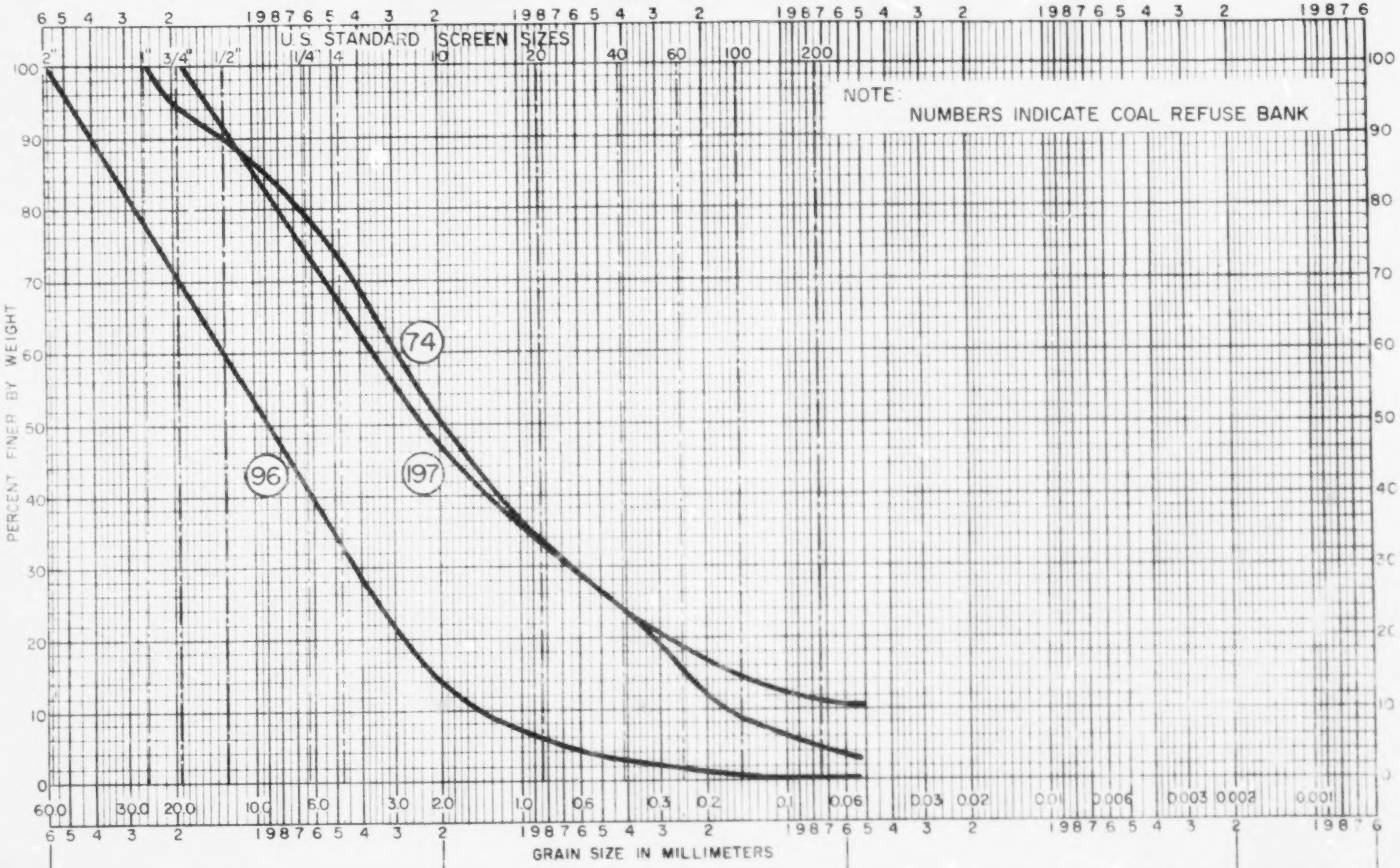
MONONGAHELA RIVER BASIN MINE REFUSE STUDY
FIGURE 3—GRADATION CURVES (Cont'd.)



GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES ___			% SAND SIZES ___			% SILT SIZES ___			% CLAY SIZES ___

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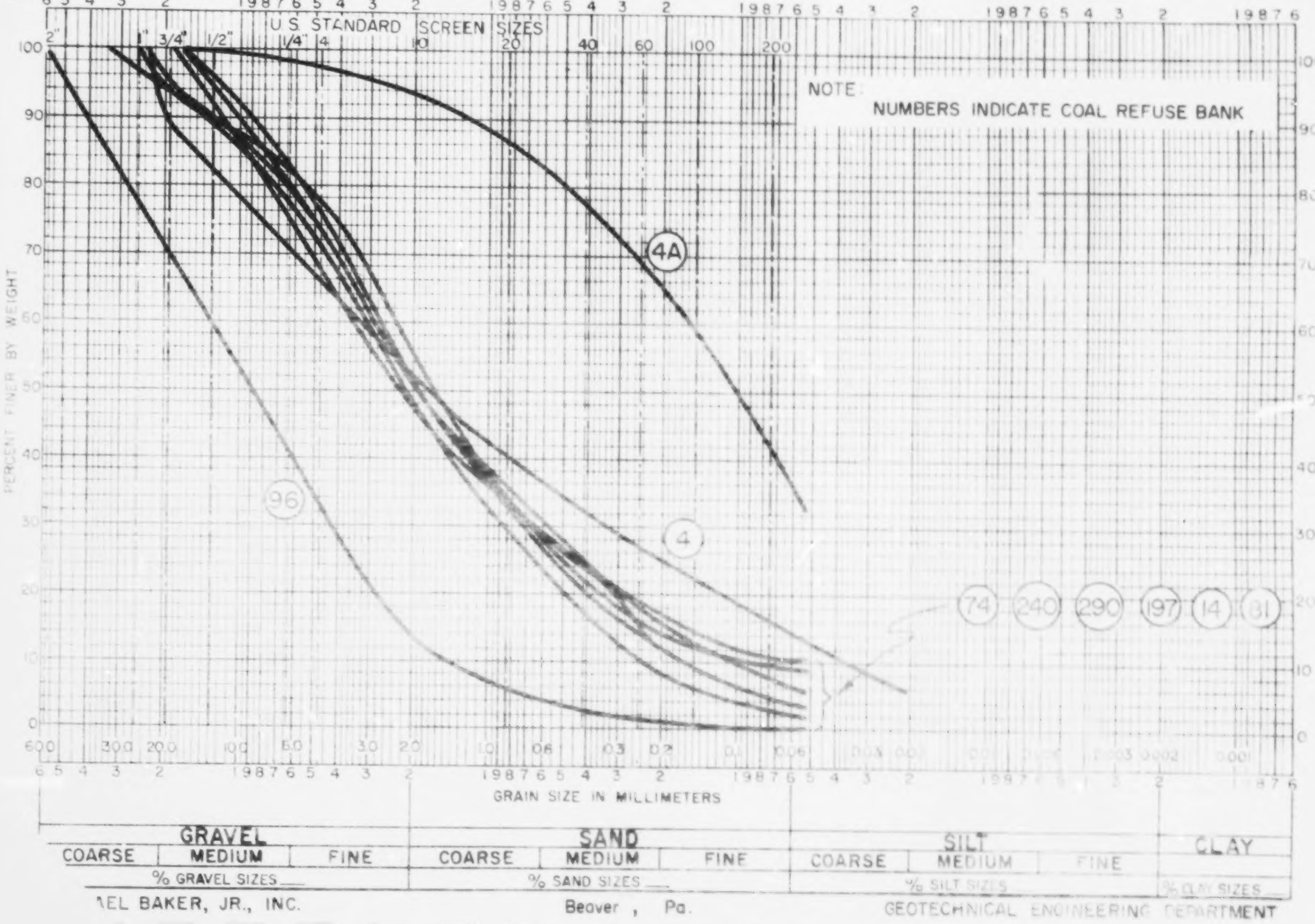
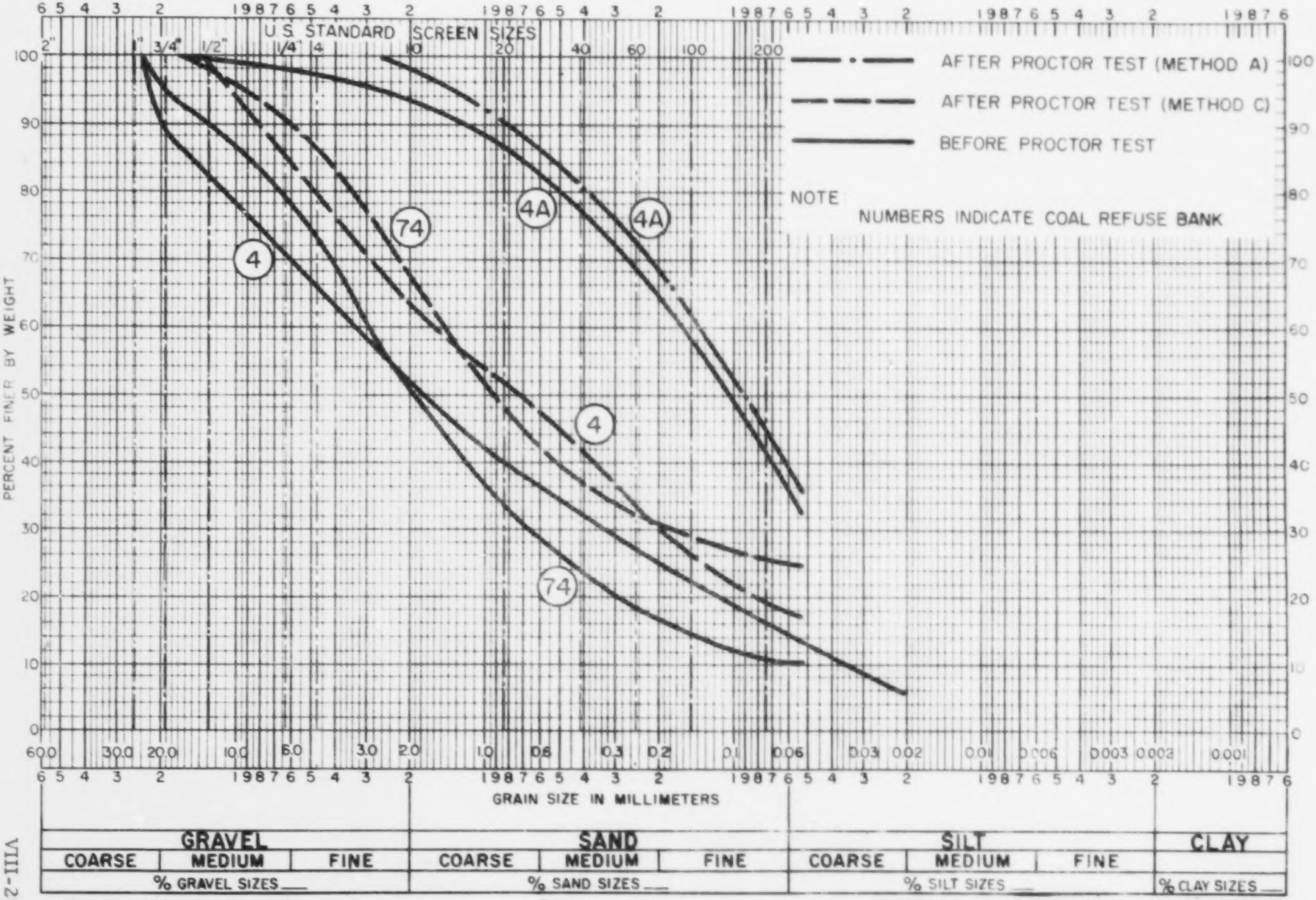
MONONGAHELA RIVER BASIN MINE REFUSE STUDY

FIGURE 4 – COMPARISON OF GRAIN SIZE DISTRIBUTION FOR ALL NINE SAMPLES



MONONGAHELA RIVER BASIN MINE REFUSE STUDY

FIGURE 5 — GRADATION CURVES BEFORE AND AFTER COMPACTION TESTS



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MONONGAHELA RIVER BASIN MINE REFUSE STUDY

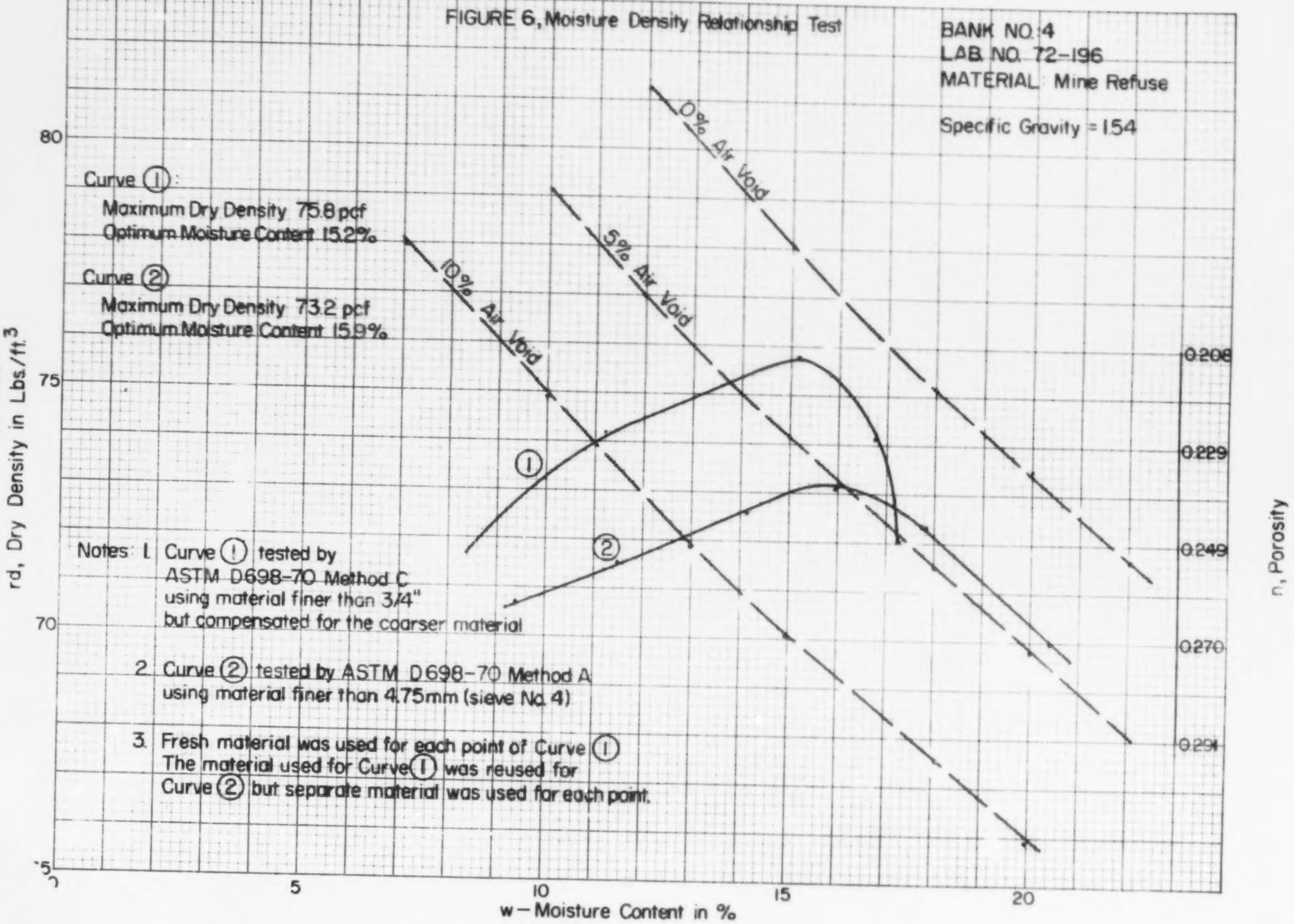


FIGURE 6, Moisture Density Relationship Test

BANK NO. 4
LAB. NO. 72-196
MATERIAL: Mine Refuse

Specific Gravity = 1.54

Curve ①:
Maximum Dry Density 75.8 pcf
Optimum Moisture Content 15.2%

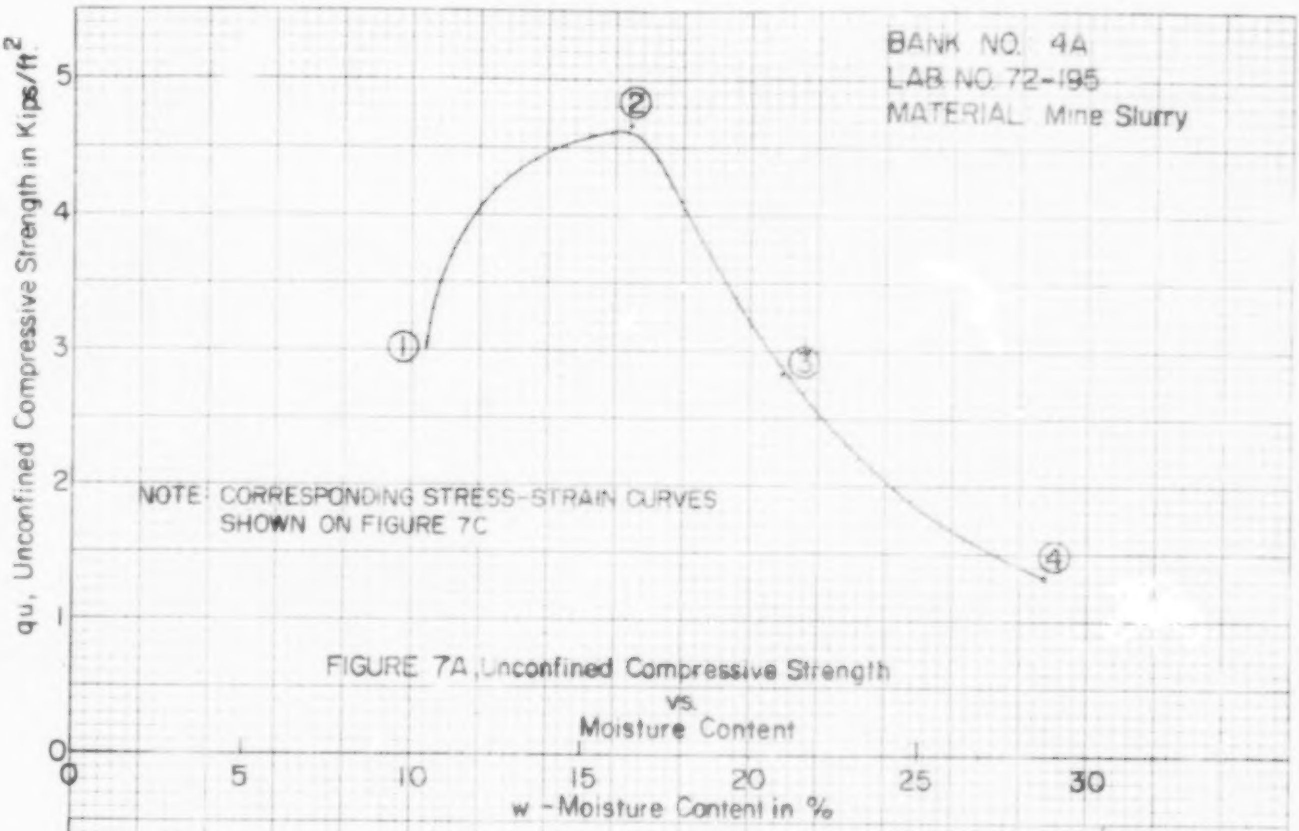
Curve ②
Maximum Dry Density 73.2 pcf
Optimum Moisture Content 15.9%

Notes: 1. Curve ① tested by ASTM D698-70 Method C using material finer than 3/4" but compensated for the coarser material

2. Curve ② tested by ASTM D698-70 Method A using material finer than 4.75mm (sieve No. 4)

3. Fresh material was used for each point of Curve ① The material used for Curve ① was reused for Curve ② but separate material was used for each point.

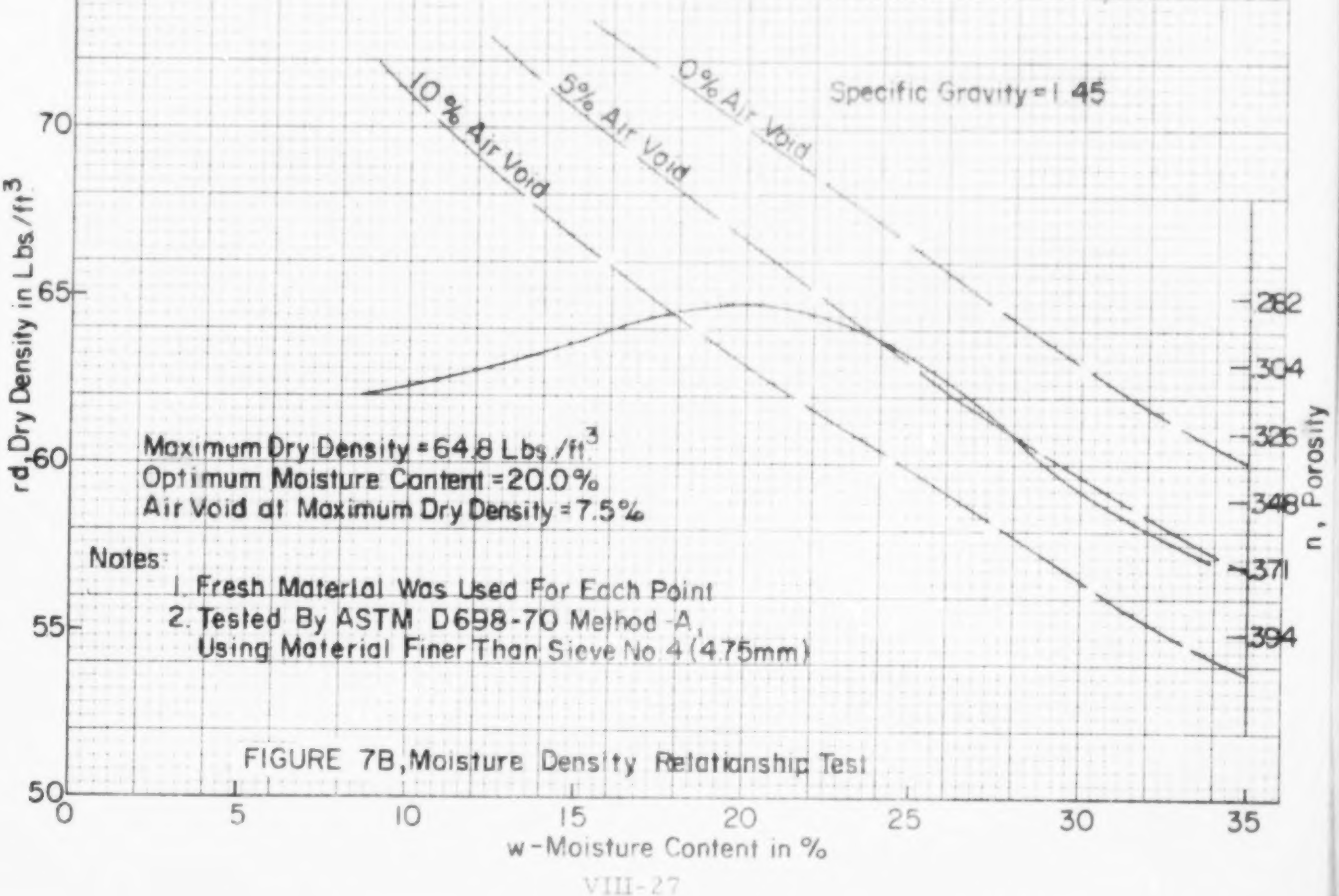
0% Air Void
5% Air Void
10% Air Void
①
②
rd, Dry Density in Lbs./ft.³
80
75
70
65
0
5
10
15
20
w – Moisture Content in %
n, Porosity
0.208
0.229
0.249
0.270
0.291



BANK NO. 4A
LAB NO. 72-195
MATERIAL: Mine Slurry

NOTE: CORRESPONDING STRESS-STRAIN CURVES SHOWN ON FIGURE 7C

FIGURE 7A, Unconfined Compressive Strength vs. Moisture Content



Maximum Dry Density = 64.8 Lbs./ft^3
Optimum Moisture Content = 20.0%
Air Void at Maximum Dry Density = 7.5%

Notes:
1. Fresh Material Was Used For Each Point
2. Tested By ASTM D698-70 Method-A, Using Material Finer Than Sieve No. 4 (4.75mm)

FIGURE 7B, Moisture Density Relationship Test

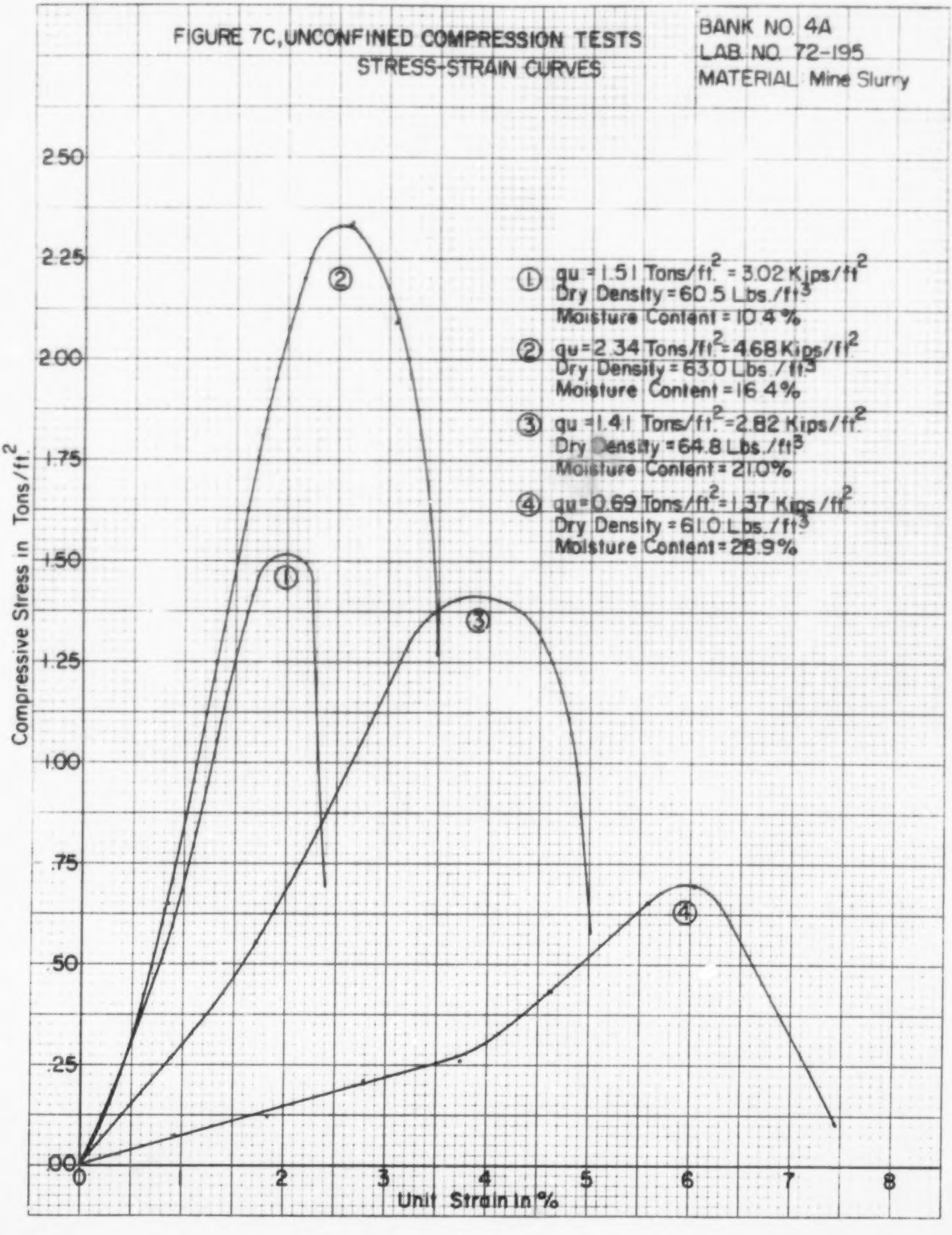


FIGURE 7C, UNCONFINED COMPRESSION TESTS
STRESS-STRAIN CURVES

MONONGAHELA RIVER BASIN MINE REFUSE STUDY

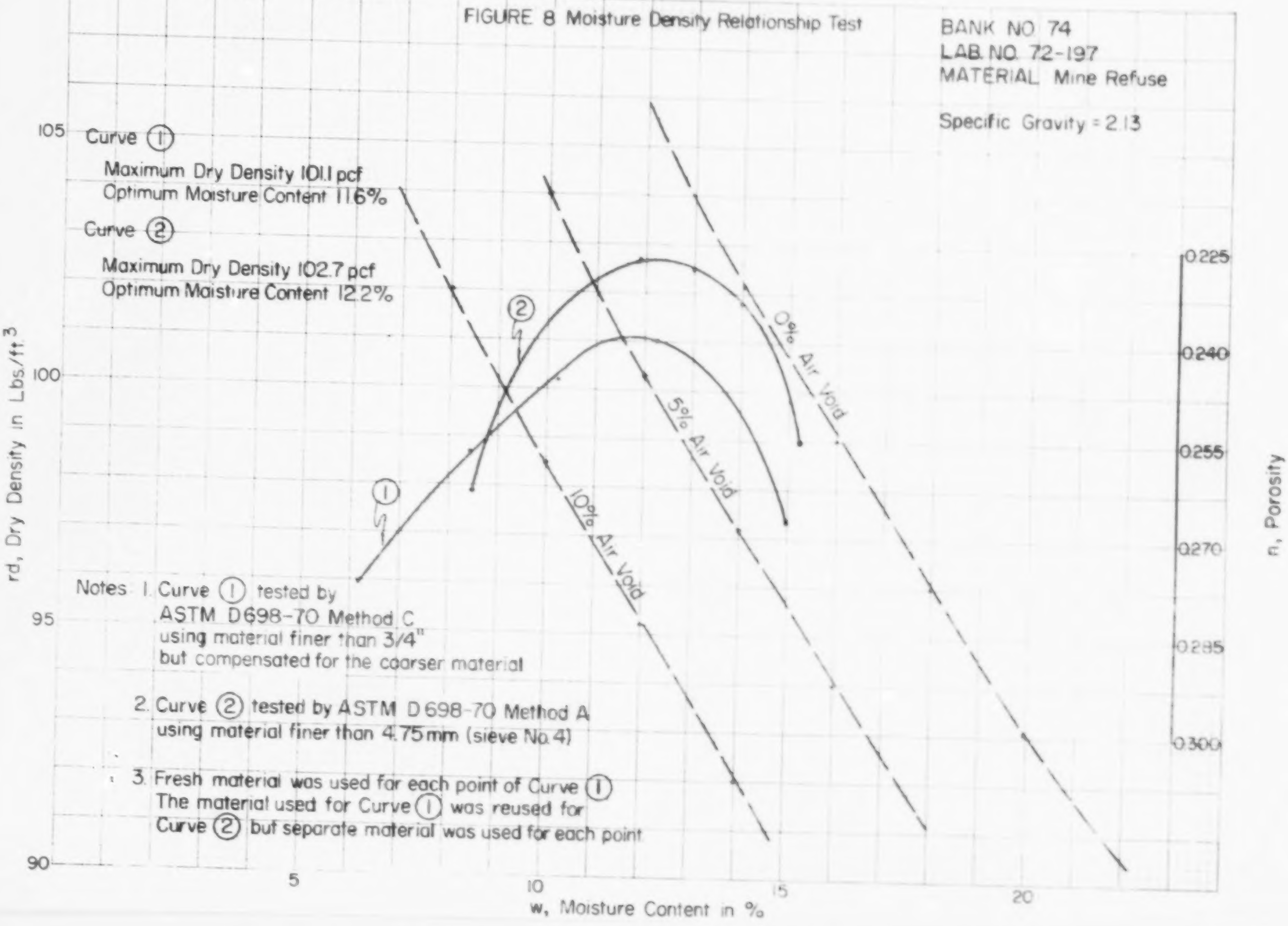


FIGURE 8 Moisture Density Relationship Test

BANK NO 74
LAB. NO. 72-197
MATERIAL Mine Refuse

Specific Gravity = 2.13

Curve ①

Maximum Dry Density 101.1 pcf
Optimum Moisture Content 11.6%

Curve ②

Maximum Dry Density 102.7 pcf
Optimum Moisture Content 12.2%

Notes: 1. Curve ① tested by ASTM D698-70 Method C using material finer than 3/4" but compensated for the coarser material

2. Curve ② tested by ASTM D698-70 Method A using material finer than 4.75 mm (sieve No. 4)

3. Fresh material was used for each point of Curve ①. The material used for Curve ① was reused for Curve ② but separate material was used for each point

rd, Dry Density in Lbs/ft.^{3}
105
100
95
90
w, Moisture Content in %
5
10
15
20
n, Porosity
0.225
0.240
0.255
0.270
0.285
0.300
0% Air Void
5% Air Void
10% Air Void
①
②

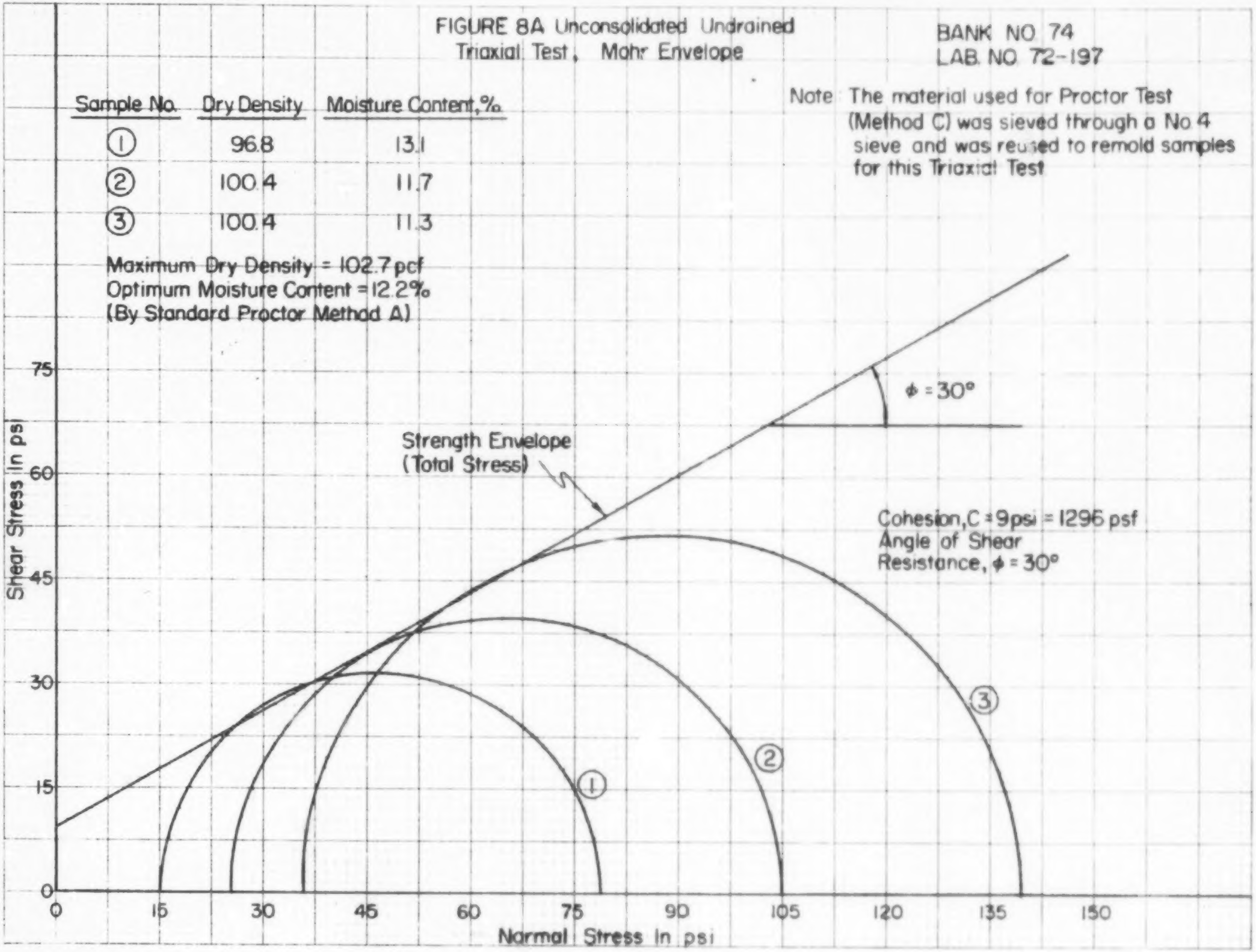


FIGURE 8A Unconsolidated Undrained Triaxial Test, Mohr Envelope

BANK NO 74
LAB NO 72-197

Sample No.	Dry Density	Moisture Content, %
①	96.8	13.1
②	100.4	11.7
③	100.4	11.3

Maximum Dry Density = 102.7 pcf
Optimum Moisture Content = 12.2%
(By Standard Proctor Method A)

Note: The material used for Proctor Test (Method C) was sieved through a No 4 sieve and was reused to remold samples for this Triaxial Test

Cohesion, C = 9psi = 1296 psf
Angle of Shear Resistance, $\phi = 30°$

Strength Envelope (Total Stress)
$\phi = 30°$
①
②
③
Shear Stress In psi
0
15
30
45
60
75
0
15
30
45
60
75
90
105
120
135
150
Normal Stress In psi

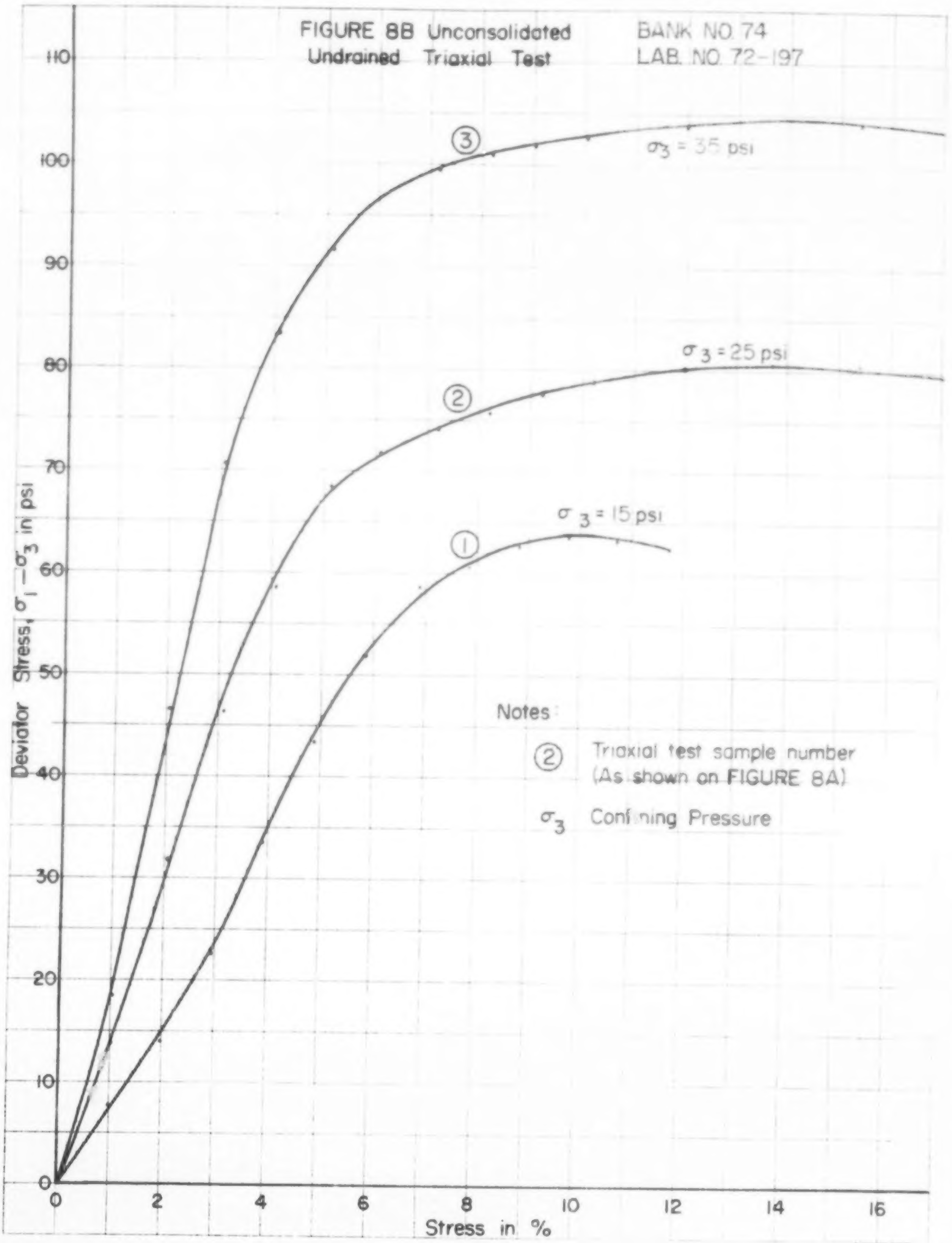


FIGURE 8B Unconsolidated Undrained Triaxial Test

BANK NO. 74
LAB. NO. 72-197

MONONGAHELA RIVER BASIN MINE REFUSE STUDY

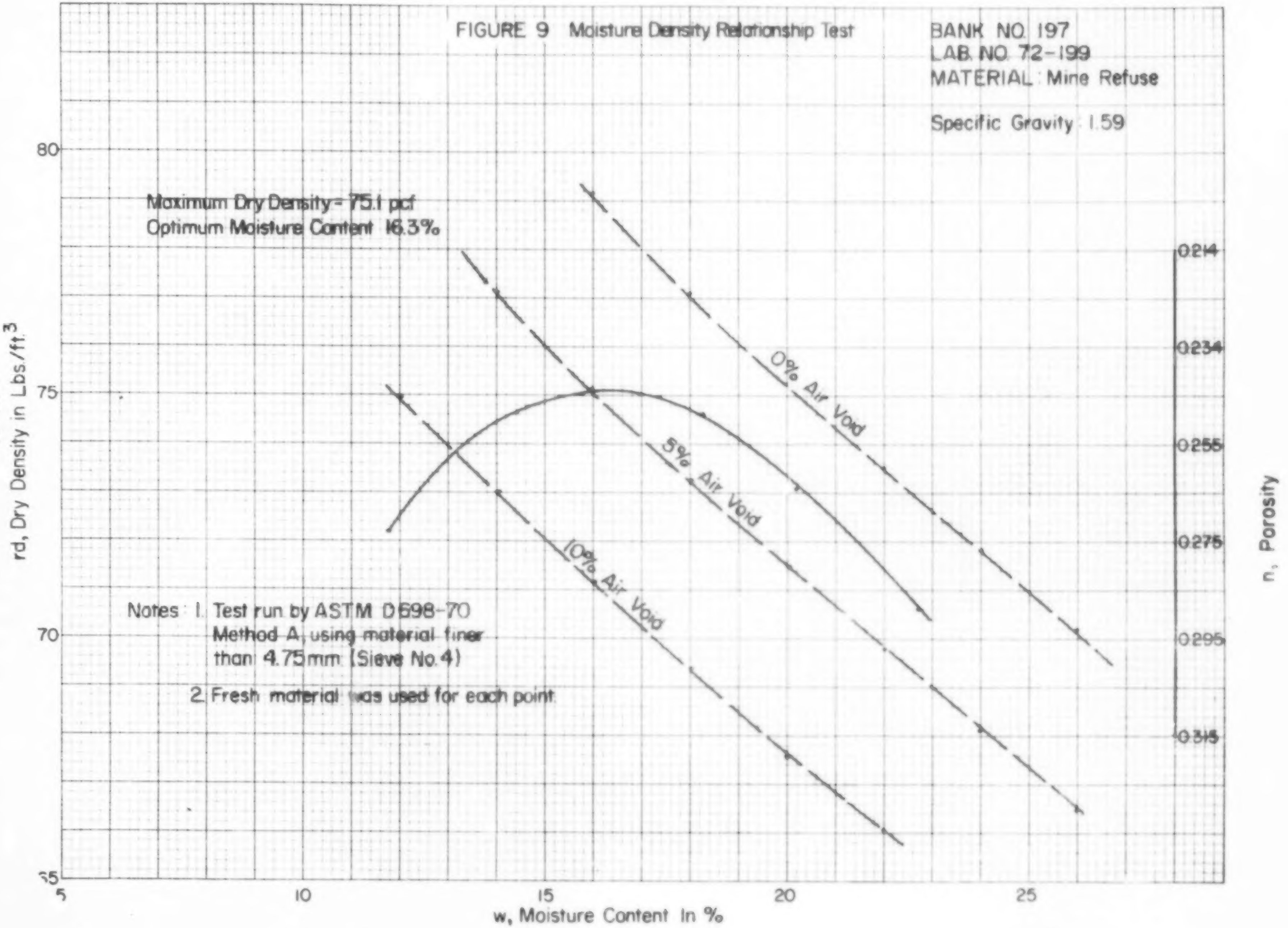


FIGURE 9 Moisture Density Relationship Test

BANK NO. 197
LAB. NO. 72-199
MATERIAL: Mine Refuse

Specific Gravity: 1.59

Maximum Dry Density = 75.1 pcf
Optimum Moisture Content 16.3%

Notes: 1. Test run by ASTM D698-70
Method A, using material finer
than 4.75mm (Sieve No.4)

2. Fresh material was used for each point

MONONGAHELA RIVER BASIN MINE REFUSE STUDY

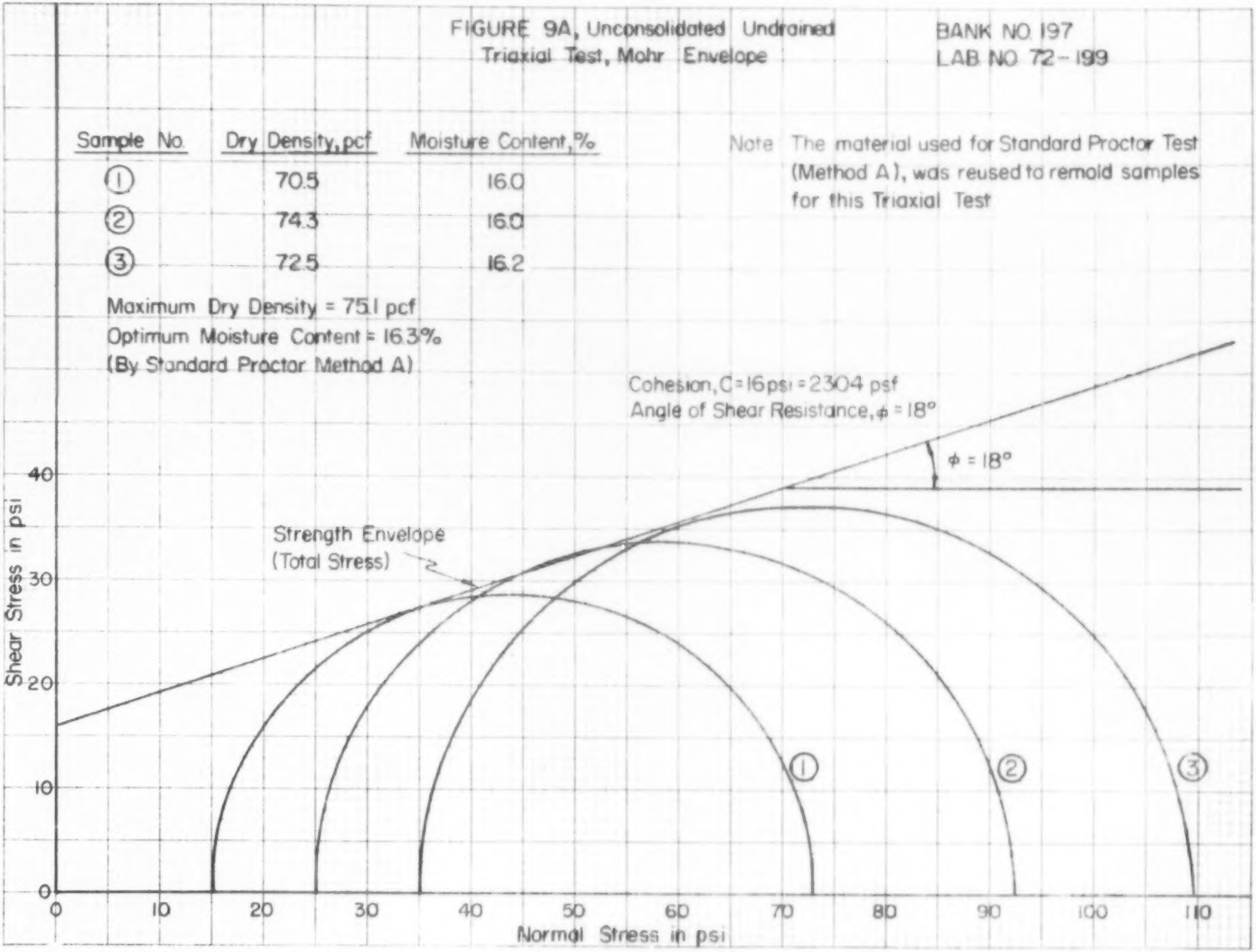


FIGURE 9A, Unconsolidated Undrained Triaxial Test, Mohr Envelope

BANK NO. 197
LAB NO. 72-199

Sample No.	Dry Density, pcf	Moisture Content, %
①	70.5	16.0
②	74.3	16.0
③	72.5	16.2

Maximum Dry Density = 75.1 pcf
Optimum Moisture Content = 16.3%
(By Standard Proctor Method A)

Note The material used for Standard Proctor Test (Method A), was reused to remold samples for this Triaxial Test

Cohesion, C = 16 psi = 2304 psf
Angle of Shear Resistance, $\phi = 18°$

Strength Envelope
(Total Stress)
$\phi = 18°$
①
②
③
Shear Stress in psi
0
10
20
30
40
Normal Stress in psi
0
10
20
30
40
50
60
70
80
90
100
110

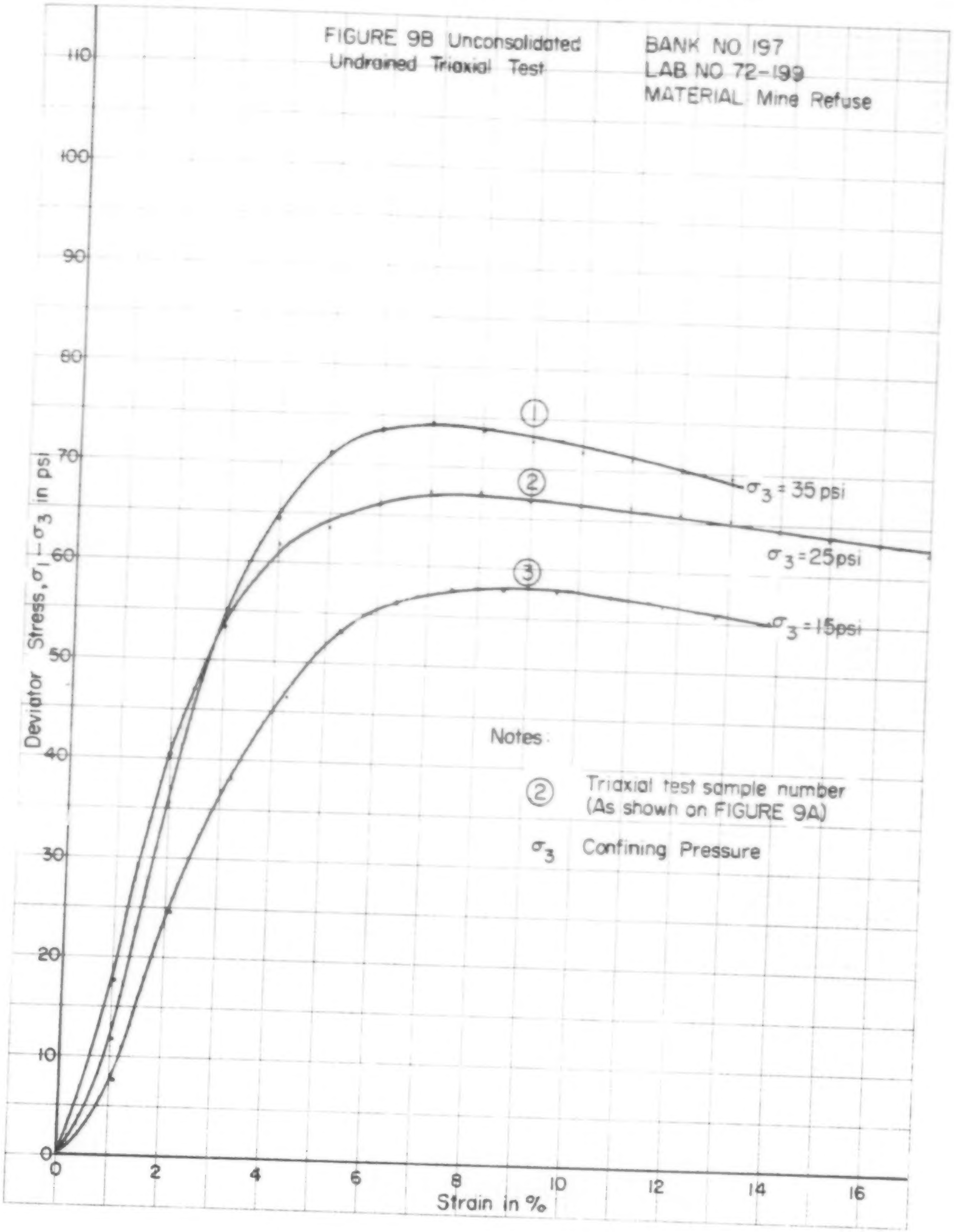
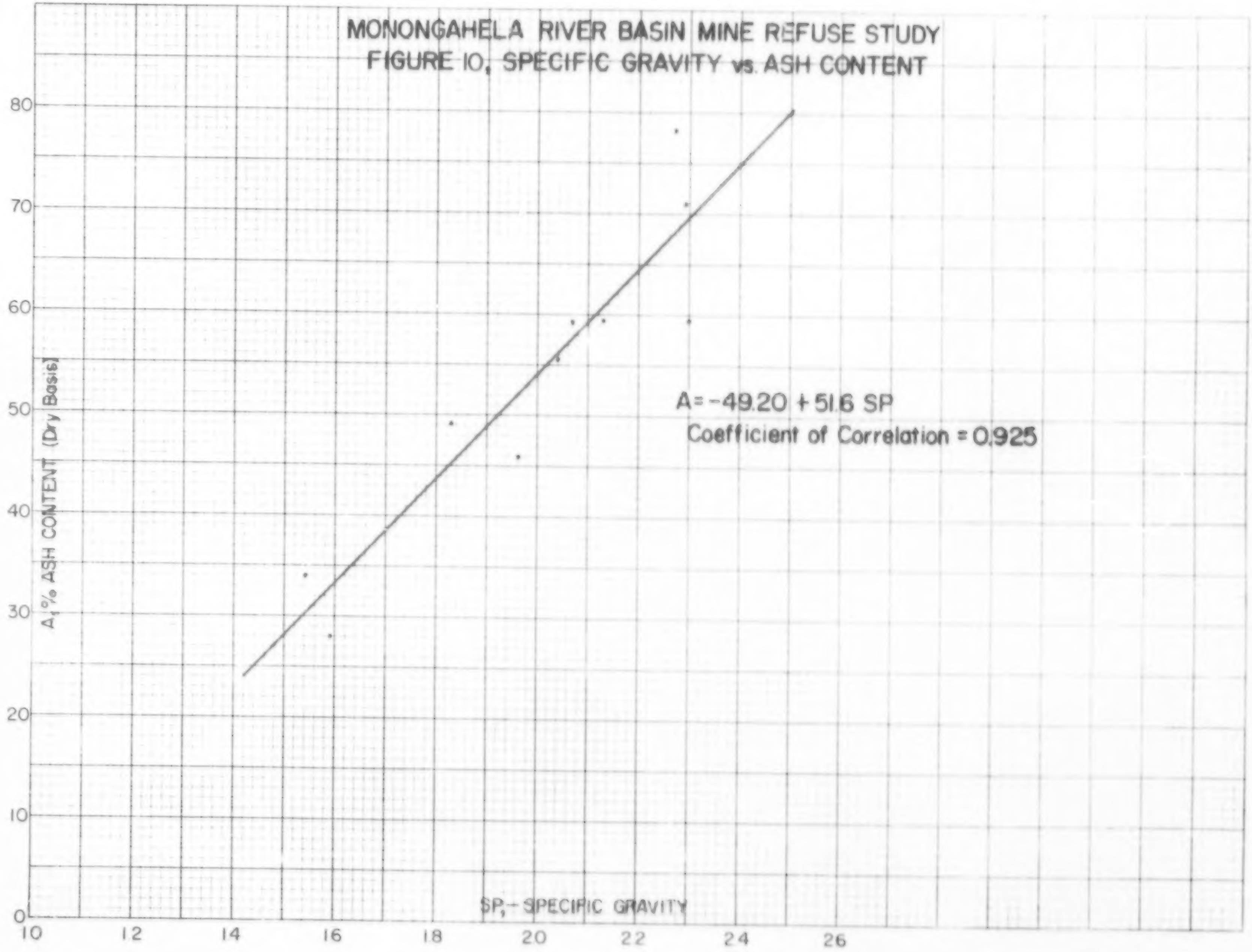
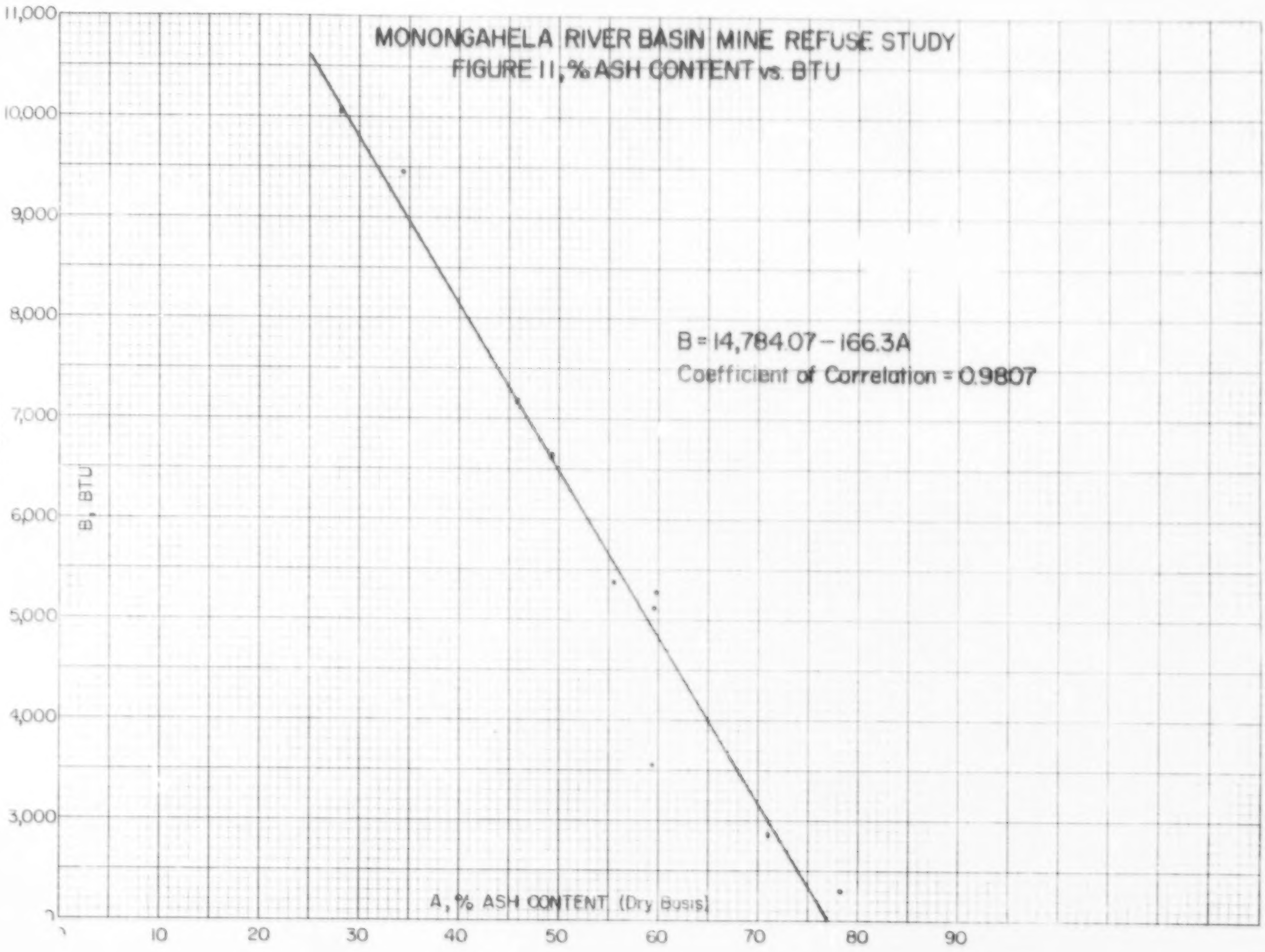


FIGURE 9B Unconsolidated Undrained Triaxial Test

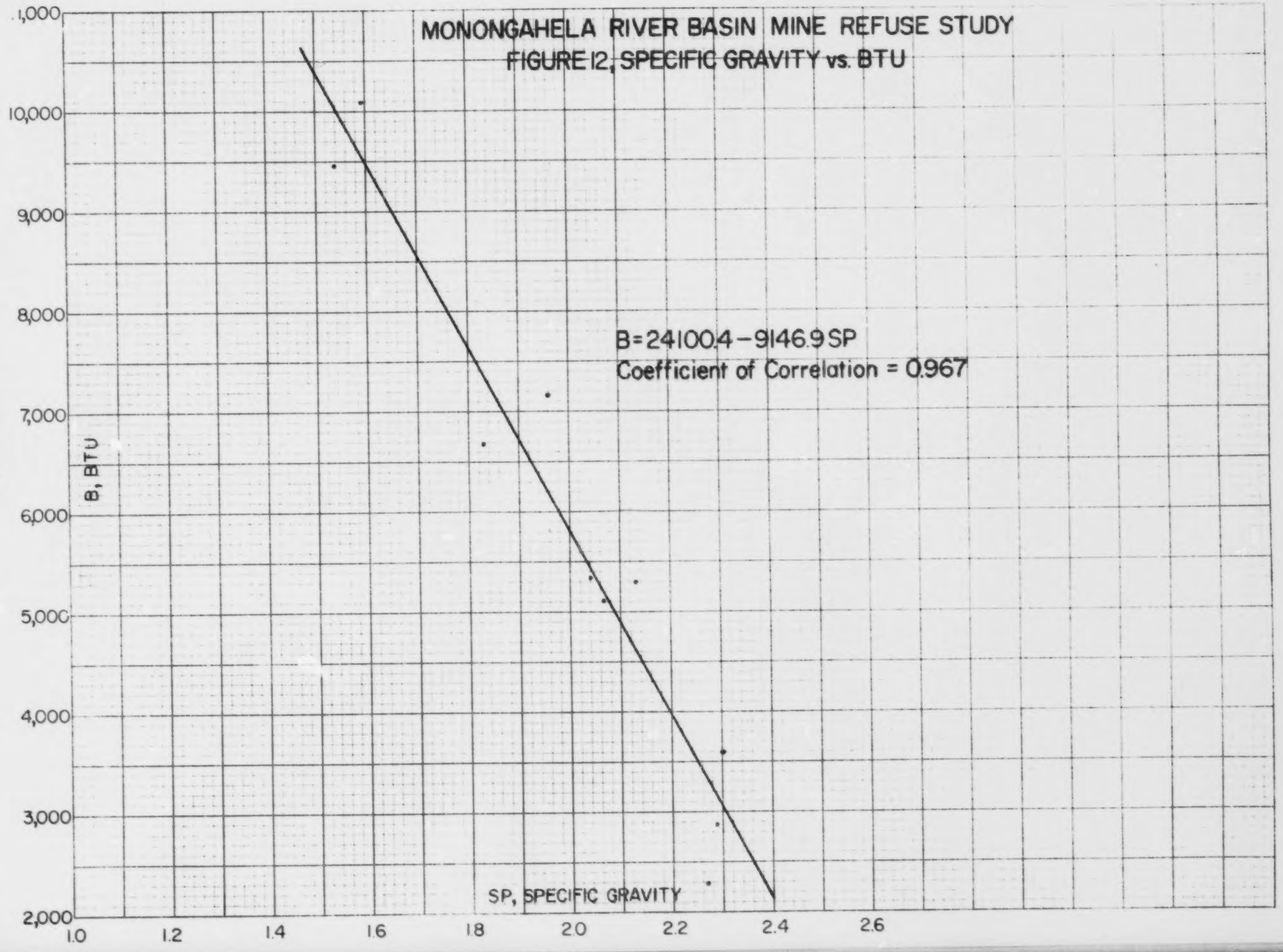


MONONGAHELA RIVER BASIN MINE REFUSE STUDY
FIGURE 10, SPECIFIC GRAVITY vs. ASH CONTENT



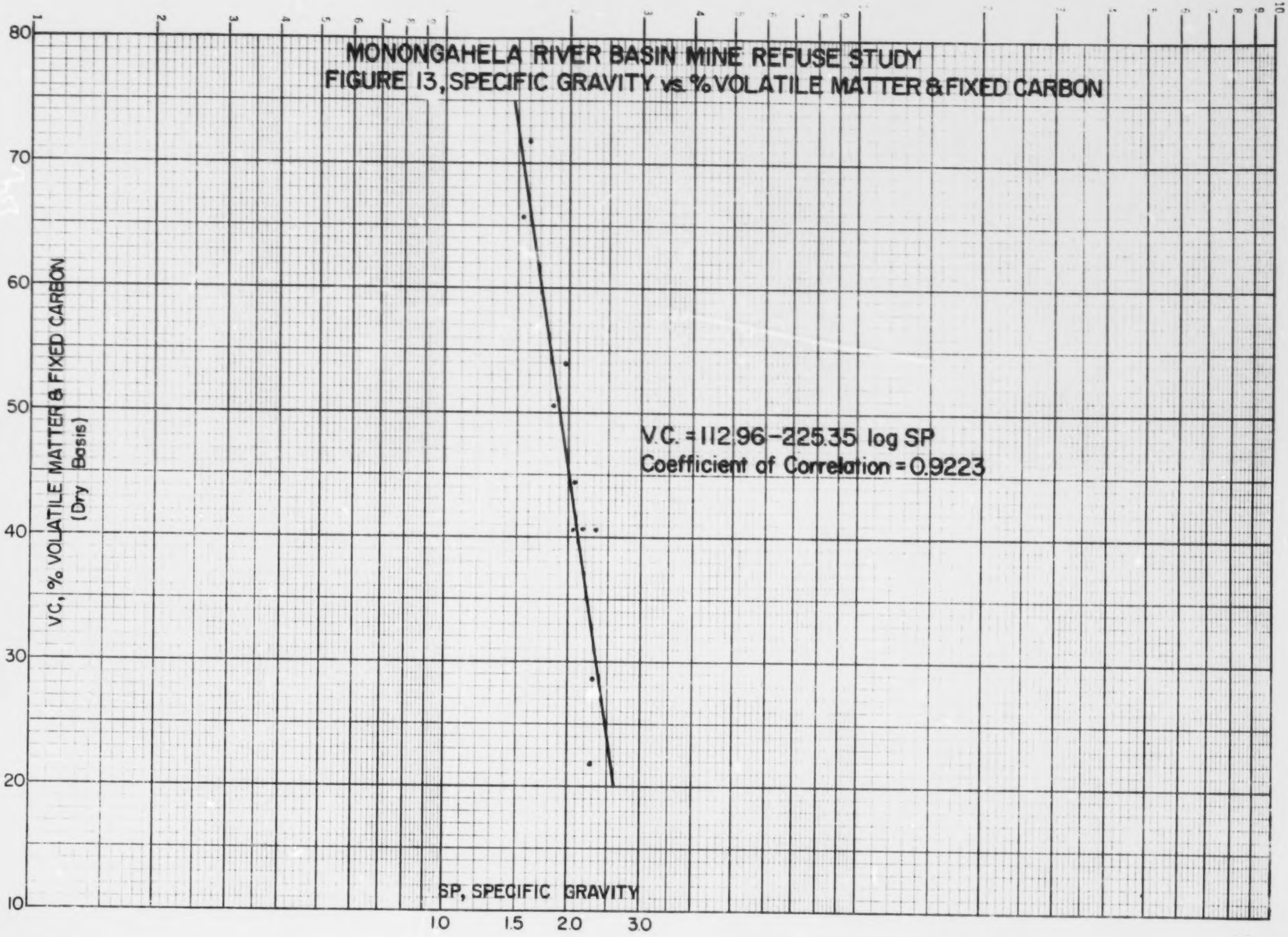
MONONGAHELA RIVER BASIN MINE REFUSE STUDY
FIGURE 11, % ASH CONTENT vs. BTU

B = 14,784.07 – 166.3A
Coefficient of Correlation = 0.9807



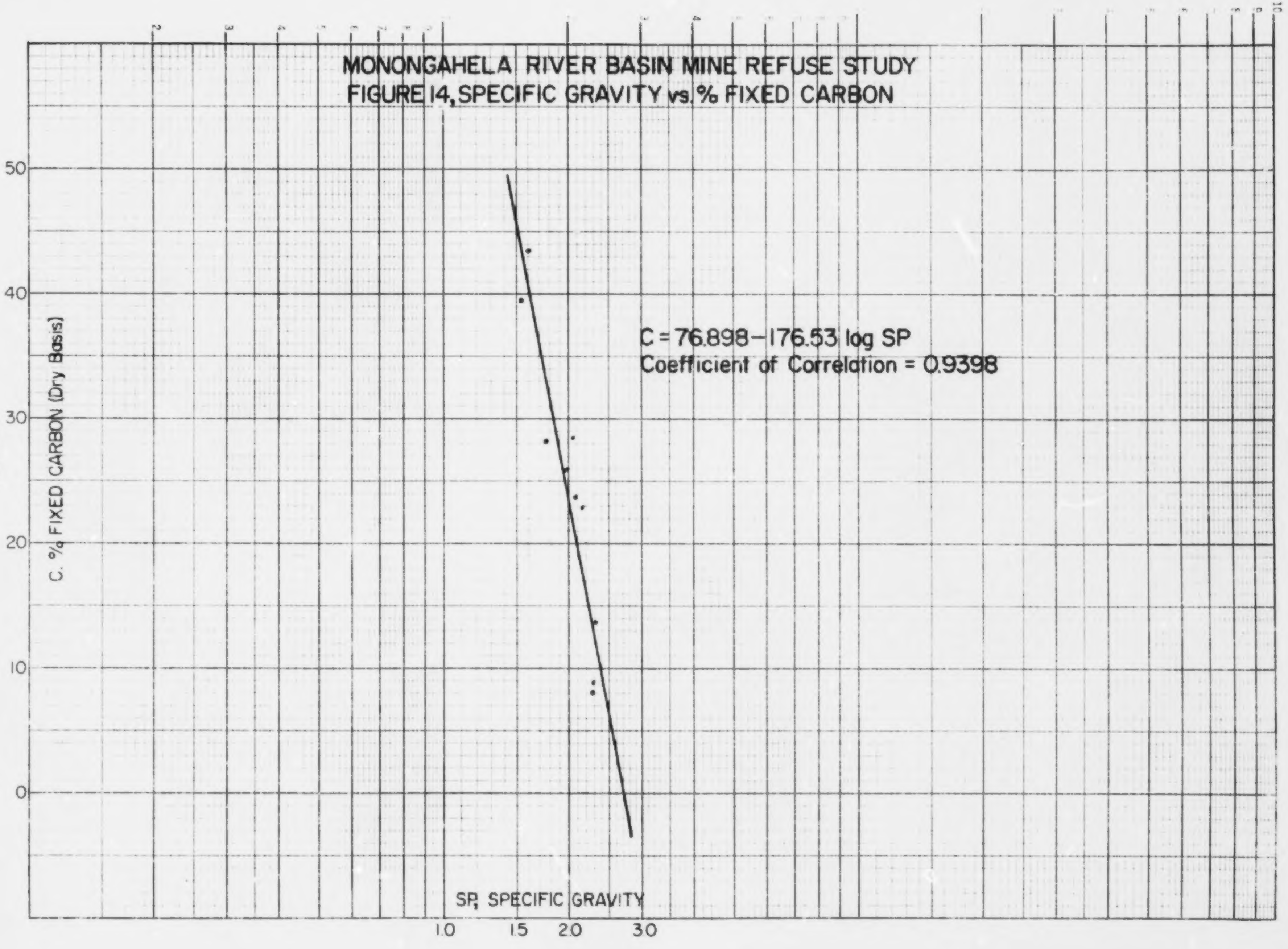
MONONGAHELA RIVER BASIN MINE REFUSE STUDY
FIGURE 12, SPECIFIC GRAVITY vs. BTU

B=24100.4 − 9146.9 SP
Coefficient of Correlation = 0.967



MONONGAHELA RIVER BASIN MINE REFUSE STUDY
FIGURE 13, SPECIFIC GRAVITY vs. % VOLATILE MATTER & FIXED CARBON

V.C. = 112.96 − 225.35 log SP
Coefficient of Correlation = 0.9223



MONONGAHELA RIVER BASIN MINE REFUSE STUDY
FIGURE 14, SPECIFIC GRAVITY vs. % FIXED CARBON

ADDITIONAL LABORATORY INVESTIGATION OF THE ENGINEERING PROPERTIES OF BITUMINOUS COAL MINE REFUSE PERFORMED IN 1974

INTRODUCTION

As a continuation of the laboratory investigation conducted in 1972 and discussed in the previous section, three refuse banks and one slurry pond were selected for further study. The locations of the refuse banks cover Indiana, Washington, Westmoreland and Fayette Counties of southwestern Pennsylvania Bituminous coal region. The refuse banks, which were being processed for coal recovery, were purposely selected for sampling so that information regarding the reprocessing of old refuse banks for energy purposes can also be obtained.

Unlike the previous study, which demonstrated that coal refuse material had good potential as an engineering material, this section emphasizes the investigation of the engineering properties of the coal refuse material. Since physical changes, fire hazards, and pollution potential have been the major concerns in the utilization of coal refuse in engineering construction; this study concentrates on the degradation characteristics, percent air void and porosity versus density and moisture content, strength and compressibility characteristics, and permeability of coal refuse in terms of applied static pressures. This study does not and can not provide all the answers for the problems associated with the utilization of coal refuse in engineering purposes. However, based on the findings revealed from the limited study conducted on the refuse banks and slurry pond selected, this study has achieved a better understanding of the engineering properties of coal refuse and provides a basis for more vigorous study on this subject.

SAMPLING AND TESTING

One slurry pond and three refuse banks were selected for sampling. Three samples, collected at three different locations and weighing approximately 50 lbs. each, constituted 150 lb. composite samples of slurry material. This sample was identified as A-C-S. In addition, four (4) samples from the slurry pond, each weighing approximately 30 lbs., were collected at various distances from the inlet pipe for the purpose of composition analysis. The location of each sample was designated with a station number referenced to the inlet pipe. One composite sample was collected from several locations at each refuse bank for the purpose of composition analysis, each bank also consisted of two sampling locations. At each of these locations, two samples were collected, one from the depth of within 0.5 foot, another from the depth of 3.5 to 4.0 feet. All samples collected from the refuse banks for composition analysis weighed approximately 30 lbs. each. The surface samples collected within 0.5 foot weighed between 20 and 30 lbs. Each surface sample was identified with a letter "S" behind the identification code of bank and sampling location such as: B-1-S, B-2-S, C-1-S, etc. All the samples collected between the depth of 3.5 to 4.0 feet, weighing approximately 70 to 100 lbs. each, were identified with a letter

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"D", such as: B-1-D, B-2-D, C-1-D, etc. The general information for each coal refuse disposal site sampled in October, 1974 is presented in Table 1.

Performed in this study were gradation, Atterberg Limits, specific gravity, compaction, strength, consolidation, California Bearing Ratio (CBR) and permeability tests. The composition analysis was performed by others under a subcontract. Except for consolidation, CBR, and permeability tests, the significance and purpose of each test was briefly illustrated in the previous section. Consequently, no description of these tests will be made here.

The permeability test is performed to determine the coefficient of permeability, which indicates the ease with which water will flow through the material. The two most important properties furnished by a consolidation test are (1) the compression index, C_c, which indicates the compressibility of the material, and (2) the coefficient of consolidation, C_v, which indicates the rate of compression under a load increment. The higher the compression index, the more compressible the material is. The higher the coefficient of consolidation, the faster the rate of compression of the material is. The CBR test is performed to measure the shearing resistance of the material under controlled moisture and density conditions. The test yields a bearing-ratio number called a CBR number. The CBR number (or simply CBR) is obtained as the ratio of the unit load required to affect a certain depth of penetration of a penetration piston into a compacted material at some water content and density to the "standard unit load" required to obtain the same depth of piston penetration on a standard sample of crushed stone.

A total of twenty-nine (29) gradation tests were performed: thirteen (13) were run prior to other testing, seven (7) were performed after the compaction tests, and nine (9) were run after the CBR tests. Summaries of the gradation and Atterberg Limits tests are shown in Tables 4 and 5. All gradation curves are shown in Exhibit A. Nine (9) specific gravity tests were performed and the results are presented in Table 6. Three (3) specific gravity tests were performed on the material finer than sieve No. 60 (0.25 mm); the remainder of the specific gravity tests were all performed on the material finer than sieve No. 10 (2.00 mm). Testing with material finer than sieve No. 60 avoided a negative percent air void at the maximum dry density for certain samples, which resulted from calculations using specific gravities obtained from the material finer than a No. 10 sieve.

A total of twelve (12) laboratory compaction tests were performed. Six were run using Standard Proctor Method A, and six were run using Standard Proctor Method C. Standard Proctor Method A uses a standard 4 inch mold and the material finer than the No. 4 (4.76 mm) sieve. Standard Proctor Method C uses a standard 4 inch mold and the material finer than a 3/4 inch sieve. The material passing the 2 inch sieve and retained on the 3/4 inch sieve was replaced with equal amount by weight of the material passing the 3/4 inch sieve but retained on a No. 4 sieve. All the compaction test results and their relationship with percent air void and porosity are shown in Exhibit B. Three sets of CBR tests were performed, the test results including the relationship between the CBR and dry density of the material are all presented in Exhibit C.

Five (5) unconfined compression tests were performed on the slurry material. The results are presented in Exhibit B on the figure where compaction results are presented. Each unconfined compression test was performed on a separate portion of the same material, representing different degrees of compaction and molding moisture content. Four (4) sets of Consolidate-Undrained Triaxial tests were performed. Only small size samples with an approximate diameter of 1.5 inches and a length of 3 inches were tested because of the limitations of the equipment. Consequently, all the triaxial samples were fabricated with the material passing a No. 4 sieve. All the triaxial test results are shown in Exhibit D, which includes stress-strain curves and strength envelopes for both total and effective stress conditions. The effective strength envelopes were obtained by subtracting the developed pore water pressures from the total stress conditions.

A total of eight (8) consolidation tests were performed on four (4) different samples. Two (2) consolidation tests on specimens with two different densities were run for each sample to investigate the effect of density on compressibility. All the test results are shown in Exhibit E. Also shown in Exhibit E are three sets of permeability results versus applied pressures. These results were calculated using the data obtained from consolidation tests. A total of four (4) permeability tests were run on samples A-C-S and D-1-D. Two tests on specimens with two different densities were performed on each sample. All the permeability test results are presented in Exhibit E. Two additional permeability tests were also run, one test for each of samples B-1-D and C-1-D. These samples were compacted to a dry density equivalent to 97 percent and 95 percent of the maximum dry density determined by Standard Proctor Method A. However, due to the almost impervious nature of the material and the limitation of time, the tests on samples B-1-D and C-1-D were discontinued four days after their commencement.

All the testing was performed in accordance with the most current ASTM standards where they are applicable. The details of the testing conditions for each test are described individually on the test results sheets presented in the Exhibits.

DISCUSSION OF TEST RESULTS

In order to investigate the effect of weathering on the degradation of the coal refuse, gradation tests were performed for the samples collected both from the surface (0 to 0.5 foot) and below the surface at the same location between the depths of 3.5 feet to 4.0 feet. A total of six (6) sampling locations, two from each refuse bank, were selected. One gradation test was performed for each of the surface samples and subsurface samples.

Consequently, two sets of six gradation test results were obtained for both the surface samples and subsurface samples. After comparison and as shown in Table 4, it was noted that the surface samples had slightly more fine material than the subsurface samples. The amount of material passing a No. 200 sieve averaged 26.7 percent for the surface samples comparing with 23.7 percent for the subsurface samples. This signified an increase of 12.7 percent on the fine particles for the surface samples as a result of weathering.

Two gradation tests were performed for each of the six subsurface samples, one before and one after the compaction test using Standard Proctor Method C. Comparisons were made only for the material finer than 3/4 inch. Compensation for coarse material was made in accordance with the method of preparation for the Standard Proctor Method C sample, as previously described. The first gradation test was performed after preparation of each proctor sample and before the compaction test. The second gradation test was performed for each sample after compaction. Consequently, both tests were not necessarily run on identical material from the same sample. Because of this, minor error was introduced which showed the percent of fines decrease rather than increase after the compaction test, as in the cases of samples B-1-D, C-1-D and C-2-D. If this error is corrected, the amount of material passing No. 200 for all six samples after compaction averaged 27.2 percent, compared with 23.7 percent before compaction. This indicated an increase of 12.9 percent in fines after compaction, compared with only a 9.7 percent increase in fines using the uncorrected laboratory results.

Comparisons of material gradations were also made on three CBR samples after each step of each CBR test. As shown in Table 5, the results of these comparisons indicated that breakdown of the material was quite significant when the compaction energy increased approximately from 5,000 ft.-lbs./cu. ft. to 10,000 ft.-lbs./cu. ft.; however, there was very little increase in breakdown when the energy increased approximately from 10,000 ft.-lbs./cu. ft. to 20,000 ft.-lbs./cu. ft.

Except for the slurry sample which was run on Standard Proctor Method A and for sample No. D-2-D which was run on Standard Proctor Method C, both Standard Proctor Methods A and C were performed on each of the remaining five samples. Exhibit B shows the moisture density relationship of each compaction test as well as its inter-relationship with percent air void and porosity. The results indicated that except for slurry material, all the coal refuse materials tested have air voids approximately 5 percent or less at the maximum dry densities, using percent air voids calculated with specific gravity results determined from material finer than No. 10 sieve. Three additional specific gravity test results obtained from material finer than No. 60 sieve were used to calculate the percent air voids on samples C-1-D, C-2-D, and D-2-D, because the specific gravities determined from the material finer than No. 10 sieve had resulted in negative values of percent air voids at the maximum dry densities. All the test results of specific gravity and compaction are summarized in Table 6.

The results of the five Unconfined Compression tests shown in Exhibit B indicate that the mine slurry could achieve an Unconfined Compressive Strength of up to 2,500 lbs./ft.^{2} when the material is compacted to the maximum dry density determined by Standard Proctor Method A. The triaxial test results presented in Exhibit D and Table 6 also indicate that if the mine slurry and mine waste materials are compacted to a density close to the maximum dry density determined by Standard Proctor Method A, the materials could achieve strength characteristics which are as good or better than most soils used for engineering purposes. These test results clearly enhance the conclusion drawn in the previous section that coal refuse does provide adequate strength if properly compacted.

As shown in Exhibit C, the CBR values for three samples compacted to maximum dry densities determined by Standard Proctor Method C are 8.2 percent, 23.6 percent, and 23.0 percent respectively. These values fall approximately within the range of CBR values for most soil types used for engineering purposes. This indicates that as far as strength is concerned, if the mine waste is properly compacted, it should provide adequate stability as a road bed or subgrade for highway or airport pavement.

Two consolidation tests with different molding densities were performed for each of the following four samples: A-C-S, B-1-D, C-1-D, and D-1-D. From four tests for the four specimens with an average dry density of 73.80 pcf, the average compression index was 0.0779, compared with an average compression index of 0.0527 for the four specimens with average dry density of 76.83 pcf. This indicates that when the dry density decreases from 76.83 pcf to 73.80 pcf (a decrease of 3.9%), the compression index increases from 0.0527 to 0.0779, an increase in the compressibility of 47.8 percent. All the consolidation test results are presented in Exhibit E and Table 6.

Two permeability tests conducted for the slurry material compacted to 98 percent and 99.77 percent of the maximum dry density shown the coefficient of permeability to be 1.5×10^{-4} cm/sec. and 3.5×10^{-5} cm/sec. respectively. The results obtained from two permeability tests conducted for mine refuse sample D-1-D compacted to 94 percent and 98 percent of the maximum dry density indicate the coefficient of permeability to be from 0.889×10^{-6} to 1.81×10^{-6} cm/sec. Additional tests performed for mine waste samples B-1-D and C-1-D compacted to 97 percent and 95 percent of the maximum dry density show the materials were almost impervious. All the permeability specimens were remolded with material finer than No. 4 sieve. Consequently, all comparisons with maximum dry densities are based on the results obtained from Standard Proctor Method A. The tests indicate that when the slurry material is compacted to a density close to maximum dry density, the material can be classified as having low permeability; and as for the mine waste, it can be classified as having very low permeability to being impervious. All these test results are shown in Exhibit E. Also shown in Exhibit E are three curves, two for sample B-1-D and one for sample C-1-D, which indicate the coefficients of permeability are very low to practically impermeable and decrease with increasing applied static pressures.

CONCLUSIONS

Based on the laboratory test results obtained in this study, the following conclusions can be made:

1. Both weathering and compaction contribute to the degradation of coal mine waste. The extent of degradation caused by weathering and compaction is approximately the same.

2. The breakdown of mine waste upon compaction is quite pronounced when the compaction energy increases approximately from 5,000 ft.-lbs./cu. ft. to 10,000 ft.-lbs./cu. ft., however, little breakdown occurs when energy increases approximately from 10,000 ft.-lbs./cu. ft. to 20,000 ft.-lbs./cu. ft.

3. When mine waste is compacted to a density equivalent to the maximum dry density determined by Standard Proctor tests, the amount of air void is generally in the vicinity of 5 percent or less.

4. The compressibility of mine waste increases substantially with slight decrease in dry density.

5. The results obtained from CBR tests and Consolidated-Undrained Triaxial tests indicate that if coal refuse is properly compacted, the material should provide adequate strength for use in landfill, embankment, and pavement subgrade.

6. The permeability test results indicate that coal refuse should have a low permeability or be practically impermeable if compacted to a density close to the maximum dry density determined by a Standard Proctor test. The coefficient of permeability also decreases substantially with increasing static pressure.

The conclusions reached above are based on the laboratory tests performed on the four coal refuse disposal sites located in Southwestern Pennsylvania. The tests performed to investigate the structural properties of coal waste used mainly the material finer than 3/4 inch or a No. 4 (4.76 mm) sieve. Consequently, those conclusions may not apply to other bituminous coal refuse. Despite these limitations, the results of this study have achieved a better understanding of the engineering behavior of coal refuse and provided a better guideline for the utilization of coal waste for engineering purposes. Further, the conclusions of this study enhance the conclusion reached in the previous section: if properly utilized, coal waste can be a good engineering material.

TABLE 1

GENERAL INFORMATION ON COAL WASTE DISPOSAL SITES SAMPLED IN 1974
WASTE BEING PROCESSED FOR COAL RECOVERY

Group Sample No.	Location	Date Sampled	Coal Seam Mined	Remarks
A	Indiana Co., Pa.	10/15/74	Upper Freeport	Inactive slurry pond. Fines deposited between 1955 and 1965. Material from cleaning plant and low in ash.
B	Washington Co., Pa.	10/ 9/74	Pittsburgh	Inactive refuse bank. Period of waste disposal not known. Burning bank containing much red dog.
C	Westmoreland Co., Pa.	10/10/74	Pittsburgh	Old refuse bank. Material not placed on bank since 1963. Refuse bank not burning now, but parts of bank have burned in past.
D	Fayette Co., Pa.	10/14/74	Pittsburgh	Old refuse bank. Some small areas show evidence of past burning.

TABLE 2
COMPOSITION OF BITUMINOUS COAL REFUSE - AS RECEIVED BASIS
PROXIMATE ANALYSIS OF COAL WASTE SAMPLES COLLECTED IN SOUTHWEST PENNSYLVANIA - 1974

County	Sample No.	Moisture %	Volatile Matter %	Fixed Carbon %	Ash %	Sulfur %	Btu
Indiana	A-C-S	12.40	26.18	51.83	9.59	1.14	11,975
	0+00	24.90	21.37	46.56	7.17	0.52	9,989
	2+00	10.76	24.68	47.02	17.54	2.83	10,670
	4+00	6.70	29.66	55.37	8.27	1.64	13,017
	8+30	7.20	25.04	58.44	9.32	0.82	12,711
	*Average	12.39	25.38	51.84	10.37	1.39	11,672
Washington	*B-C	10.76	17.74	22.37	49.13	0.54	5,205
	B-1-D	11.16	16.99	21.51	50.34	0.54	4,895
	B-2-D	8.76	16.97	26.48	47.79	0.48	5,618
Westmoreland	*C-C	11.36	17.84	35.72	35.08	0.62	7,963
	C-1-D	8.76	18.18	37.70	35.36	1.75	8,014
	C-2-D	9.16	18.40	32.71	39.73	0.99	7,000
Fayette	*D-C	9.80	18.23	31.22	40.75	0.62	6,671
	D-1-D	9.65	20.11	41.15	29.09	0.71	8,513
	D-2-D	6.58	20.13	32.46	40.83	1.21	7,376

*Composition based on analysis of randomly selected increments of weight obtained from each disposal area.

TABLE 3
COMPOSITION OF BITUMINOUS COAL REFUSE - DRY BASIS
PROXIMATE ANALYSIS OF COAL WASTE SAMPLES COLLECTED IN SOUTHWEST PENNSYLVANIS - 1974

County	Sample No.	Volatile Matter %	Fixed Carbon %	Ash %	Sulfur %	Btu	Btu (Moisture & Ash Free)
Indiana	A-C-S	29.89	59.16	10.95	1.30	13,670	15,351
	0+00	28.45	62.00	9.55	0.69	13,301	14,705
	2+00	27.66	52.69	19.65	3.17	11,957	14,881
	4+00	31.79	59.35	8.86	1.76	13,952	15,308
	8+30	26.98	62.98	10.04	0.88	13,697	15,226
	*Average	28.95	59.24	11.81	1.56	13,315	15,094
Washington	*B-C	19.88	25.07	55.05	0.60	5,833	12,977
	B-1-D	19.12	24.22	56.66	0.61	5,510	12,713
	B-2-D	18.60	29.02	52.38	0.53	6,157	12,929
Westmoreland	*C-C	20.13	40.29	39.58	0.70	8,983	14,868
	C-1-D	19.93	41.31	38.76	1.92	8,783	14,342
	C-2-D	20.25	36.01	43.74	1.09	7,706	13,697
Fayette	*D-C	20.21	34.61	45.18	0.69	7,396	13,491
	D-1-D	22.26	45.54	32.20	0.79	9,422	13,897
	D-2-D	21.55	34.74	43.71	1.30	7,896	14,027

*Composition based on analysis of randomly selected increments of weight obtained from each disposal area.

TABLE 4
SUMMARY OF INDEX PROPERTIES TESTS

Location	Sample No.	Lab. No.	NMC (%)	Atterberg Limits (%)		Gradation, % Passing					Remarks
				Liquid Limit	Plastic Index	#4,	#10,	#60,	#200,	0.002 mm	
Indiana Co., Pa.	A-C-S	74-879-A	20.9	30	NP	100	99	74	51	5	
	A-C-S	74-879-B	20.9	30	NP	100	98	70	46	4	After compaction of 74-879-A
Washington Co., Pa.	B-1-S	74-880	10.4	29	14	76	64	48	44	16	
	B-1-D	74-881-A	9.7	32	14	90	78	52	46	18	
	B-1-D	74-881-B	9.7	32	14	86	72	49	45	18	After compaction of 74-881-A
	B-2-S	74-882	8.0	17	NP	83	75	46	41	13	
	B-2-D	74-883-A	13.7	34	11	70	54	34	30	10	
	B-2-D	74-883-B	13.7	34	11	83	69	49	44	13	After compaction of 74-883-A
Westmoreland Co., Pa.	C-1-S	74-884	10.7	28	NP	87	74	46	34	3	
	C-1-D	74-885-A	10.0	26	NP	74	61	35	24	3	
	C-1-D	74-885-B	10.0	26	NP	72	58	37	21	3	After compaction of 74-885-A
	C-2-S	74-886	8.0	27	NP	66	47	21	17	5	
	C-2-D	74-887-A	12.7	16	NP	74	60	30	19	4	
	C-2-D	74-887-B	12.7	16	NP	71	51	23	15	4	After compaction of 74-887-B
Fayette Co., Pa.	D-1-S	74-888	10.3	NO	NP	54	40	15	9	3	
	D-1-D	74-889-A	12.0	33	NP	54	36	18	12	3	
	D-1-D	74-889-B	12.0	33	NP	73	52	24	18	4	After compaction of 74-889-A
	D-2-S	74-890	9.4	31	NP	66	50	22	15	3	
	D-2-D	74-891-A	7.8	31	NP	49	35	14	11	3	
	D-2-D	74-891-B	7.8	31	NP	60	41	17	12	4	After compaction of 74-891-A

NOTES:
(1) NMC = Natural Moisture Content
(2) NO = Non-Obtainable
(3) NP = Non-Plastic
(4) All "S" Samples were obtained within 0.5' from the surface.
(5) All "D" Samples were obtained between the depths of 3.5' to 4.0'.

TABLE 5
COMPARISON OF GRADATION AFTER EACH STEP OF C.B.R. TEST

Location	Sample No.	Lab. No.	Gradation, % Passing #4.	#10.	#60.	#200.	0.002 mm	Compactive Effort ft.-lb./cu. ft.	Number of Blows Per Layer	Step
Washington Co., Pa.	B-2-D	74-883	84	69	50	46	15	5,499	25	Step
	B-2-D	74-883	95	80	61	57	23	8,798	40	Step
	B-2-D	74-883	87	77	59	56	21	19,795	90	Step
Westmoreland Co., Pa.	C-2-D	74-887	75	53	23	16	4	5,499	25	Step
	C-2-D	74-887	72	52	23	16	4	9,898	45	Step
	C-2-D	74-887	75	55	23	16	5	20,895	95	Step
Fayette Co., Pa.	D-2-D	74-891	59	38	16	12	4	5,499	25	Step
	D-2-D	74-891	69	50	21	15	6	9,898	45	Step
	D-2-D	74-891	65	46	22	16	7	20,895	95	Step

TABLE 6
SUMMARY OF STRUCTURAL PROPERTIES TESTS

Location	Sample No.	Lab. No.	Specific Gravity	Standard Proctor				Effective Strength Parameters				Compression Index		
				Method C		Method A								
				OMC (%)	MDD (pcf)	OMC (%)	MDD (pcf)	AMC (%)	ADD (pcf)	C' (psf)	Ø' (Degree)	MC (%)	DD (pcf)	C_c
Indiana Co., Pa.	A-C-S	74-879	1.35	--	--	21.3	60	20.4	60.5	1332	34.5	20.7 25.3	61.97 58.00	0.0395 0.0720
Washington Co., Pa.	B-1-D	74-881	1.91	13.0	89.6	13.3	91.6	13.3	89.4	576	25.5	13.0 16.3	93.37 90.46	0.0638 0.0804
Washington Co., Pa.	B-2-D	74-883	1.89	13.2	90.4	13.9	90.3	14.8	89.6	2419	13.0	-- --	--- ---	-- --
Washington Co., Pa.	C-1-D	74-885	1.5 1.69(1)	9.3	85.6	10.4	80.4	9.6	78.3	0	35.0	16.6 18.6	76.28 72.85	0.051 0.075
Washington Co., Pa.	C-2-D	74-887	1.61 1.72(1)	12.7	84.4	13.8	79.9	--	--	--	--	-- --	--- ---	-- --
Fayette Co., Pa.	D-1-D	74-889	1.67	14.7	80.3	16.0	78.2	--	--	--	--	19.5 16.0	75.70 73.87	0.0565 0.0840
Fayette Co., Pa.	D-2-D	74-891	1.72(1)	12.7	84.2	--	--	--	--	--	--	--	---	--

NOTES: (1) All specific gravity tests were performed for the samples passing a No. 10 (2.00 mm) sieve except for those indicated with (1) which were tested on the samples finer than a No. 60 (0.25 mm) sieve.

(2) OMC = Optimum Moisture Content, MDD = Maximum Dry Density

(3) AMC = Average Moisture Content for all Triaxial samples, ADD = Average Dry Density for all Triaxial samples.

(4) MC = Moisture Content, DD = Dry Density

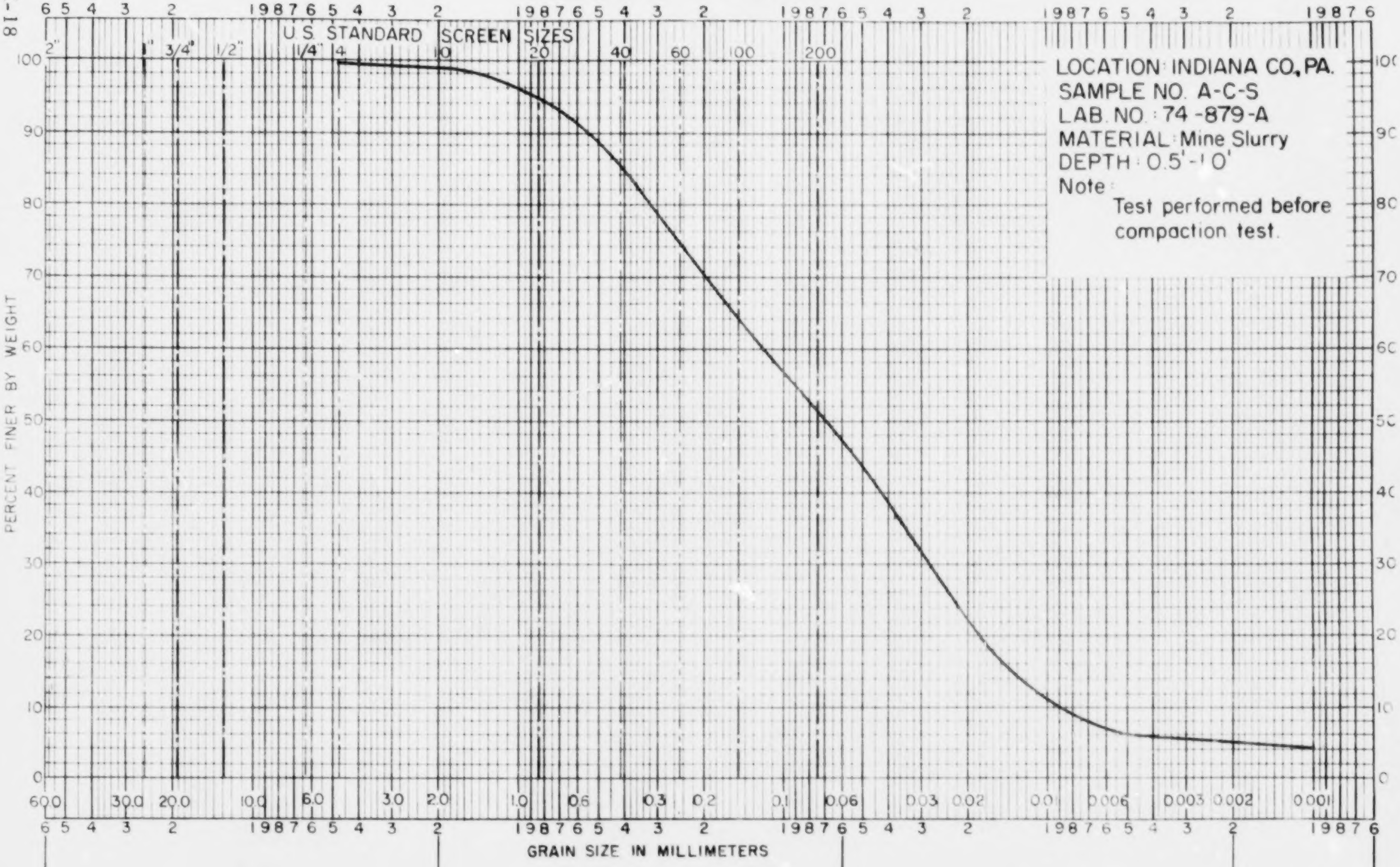
(5) C_c = Compression Index

(6) Except for % air voids where some of them were calculated with specific gravity results obtained from materials passing No. 60 sieve as indicated, all other calculations where specific gravity results are required, results obtained from material finer than No. 10 sieve were used.

EXHIBIT A

Gradation Curves

GRADATION CURVE



LOCATION: INDIANA CO, PA.
SAMPLE NO. A-C-S
LAB. NO.: 74-879-A
MATERIAL: Mine Slurry
DEPTH: 0.5'-1.0'
Note:
Test performed before compaction test.

GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES ___			% SAND SIZES ___			% SILT SIZES ___			% CLAY SIZES ___

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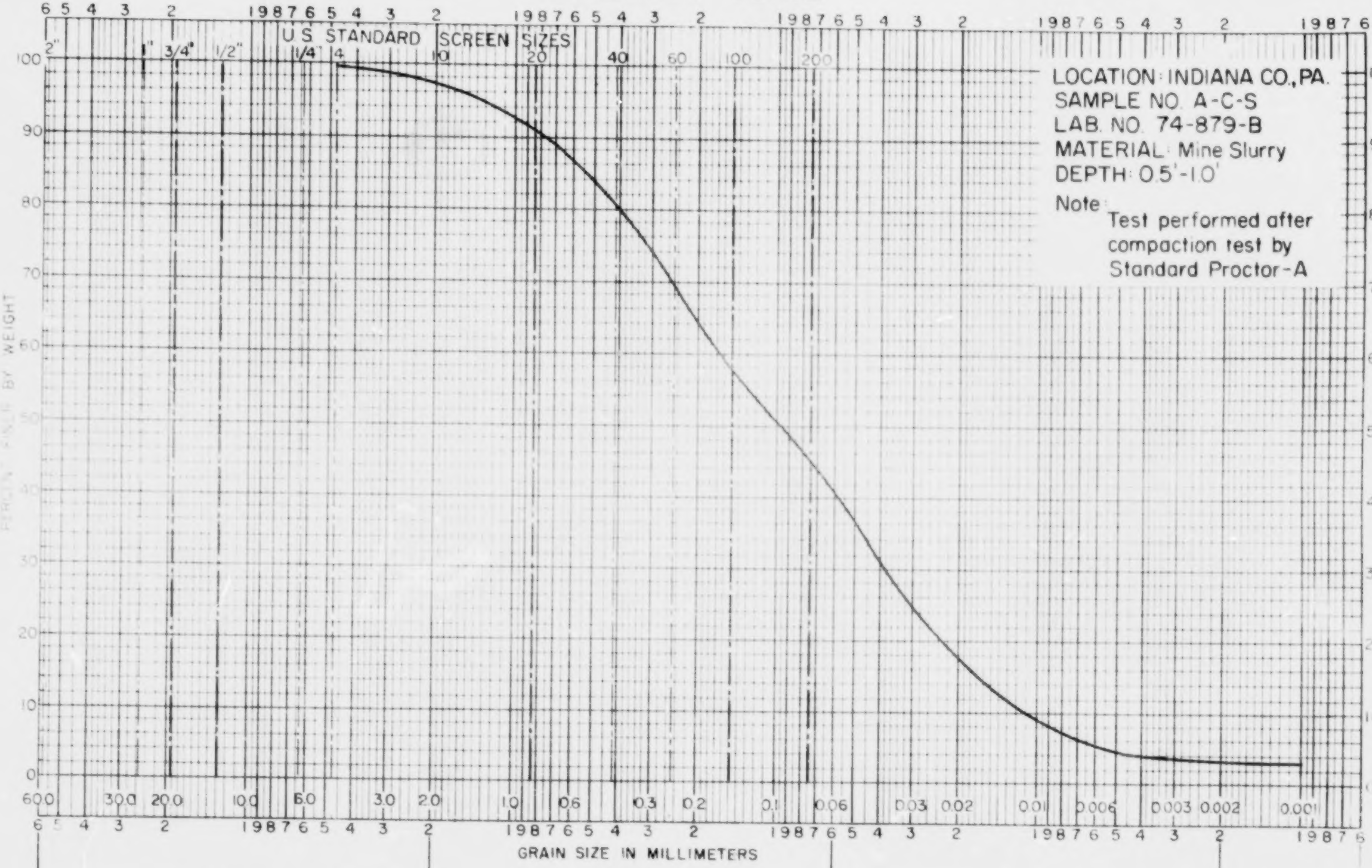
GRADATION CURVE



LOCATION: INDIANA CO., PA.
SAMPLE NO. A-C-S
LAB. NO. 74-879-B
MATERIAL: Mine Slurry
DEPTH: 0.5'-1.0'
Note:
Test performed after
compaction test by
Standard Proctor-A

GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES ___			% SAND SIZES ___			% SILT SIZES ___			% CLAY SIZES ___

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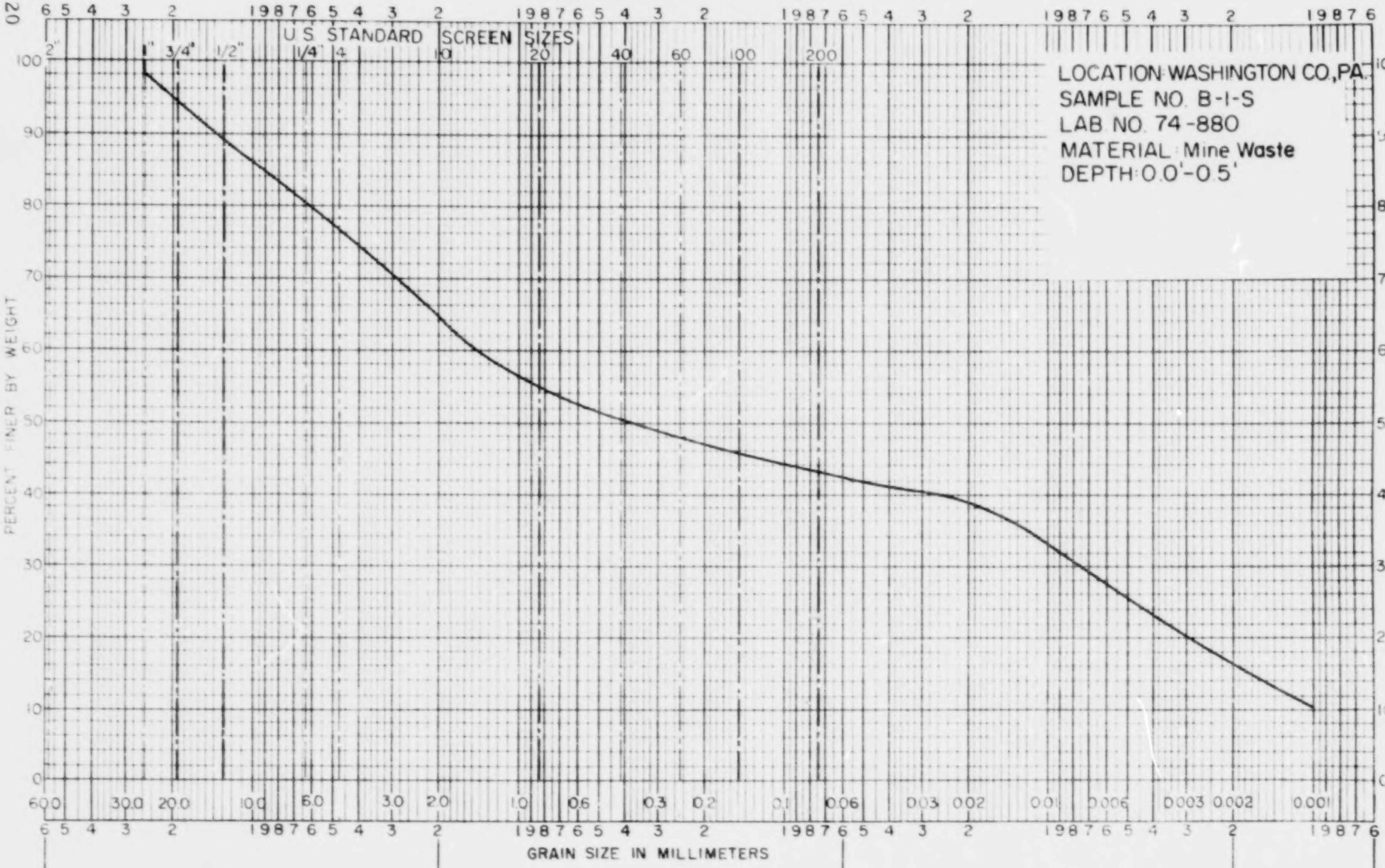
GRADATION CURVE

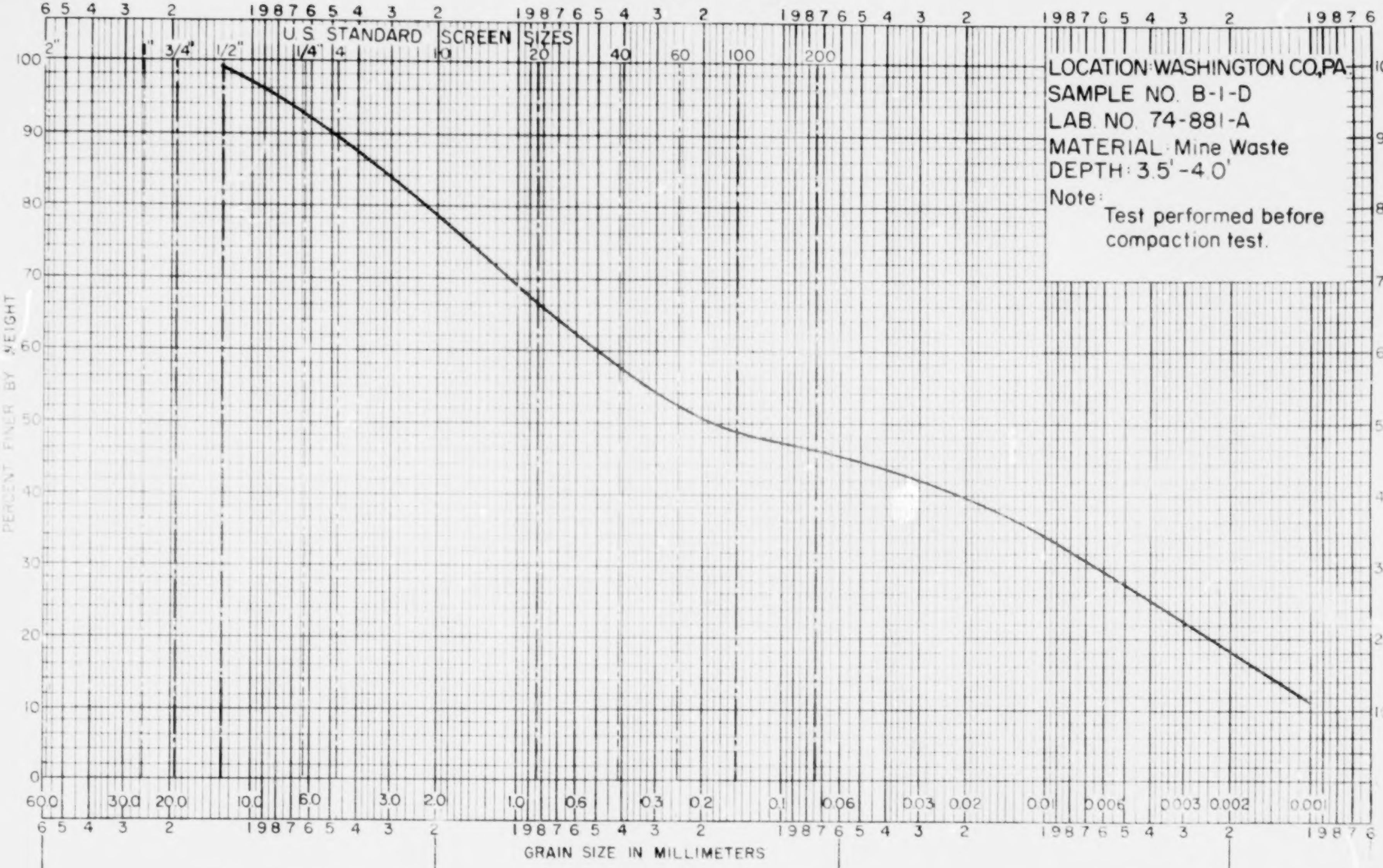


LOCATION: WASHINGTON CO., PA.
SAMPLE NO. B-1-S
LAB NO. 74-880
MATERIAL: Mine Waste
DEPTH: 0.0'-0.5'

GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES ___			% SAND SIZES ___			% SILT SIZES ___			% CLAY SIZES ___

'ICHAEL BAKER, JR., INC. Beaver, Pa. GEOTECHNICAL ENGINEERING DEPARTMENT

GRADATION CURVE

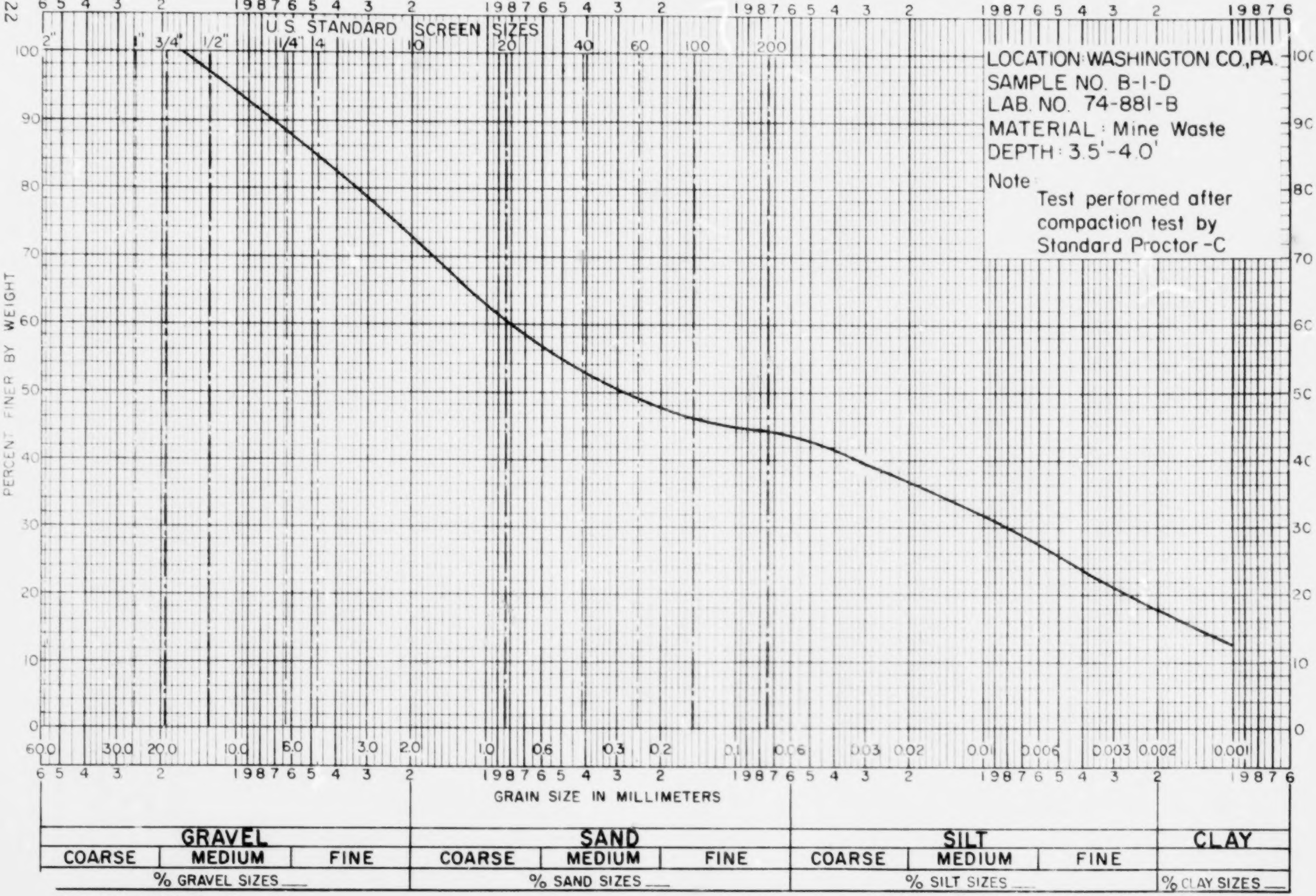


LOCATION: WASHINGTON CO., PA.
SAMPLE NO. B-1-D
LAB. NO. 74-881-A
MATERIAL: Mine Waste
DEPTH: 3.5'-4.0'
Note:
Test performed before
compaction test.

GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES ___			% SAND SIZES ___			% SILT SIZES ___			% CLAY SIZES ___

MICHAEL BAKER, JR., INC. Beaver, Pa. GEOTECHNICAL ENGINEERING DEPARTMENT

GRADATION CURVE



LOCATION: WASHINGTON CO, PA.
SAMPLE NO. B-1-D
LAB. NO. 74-881-B
MATERIAL: Mine Waste
DEPTH: 3.5'-4.0'

Note:
Test performed after compaction test by Standard Proctor -C

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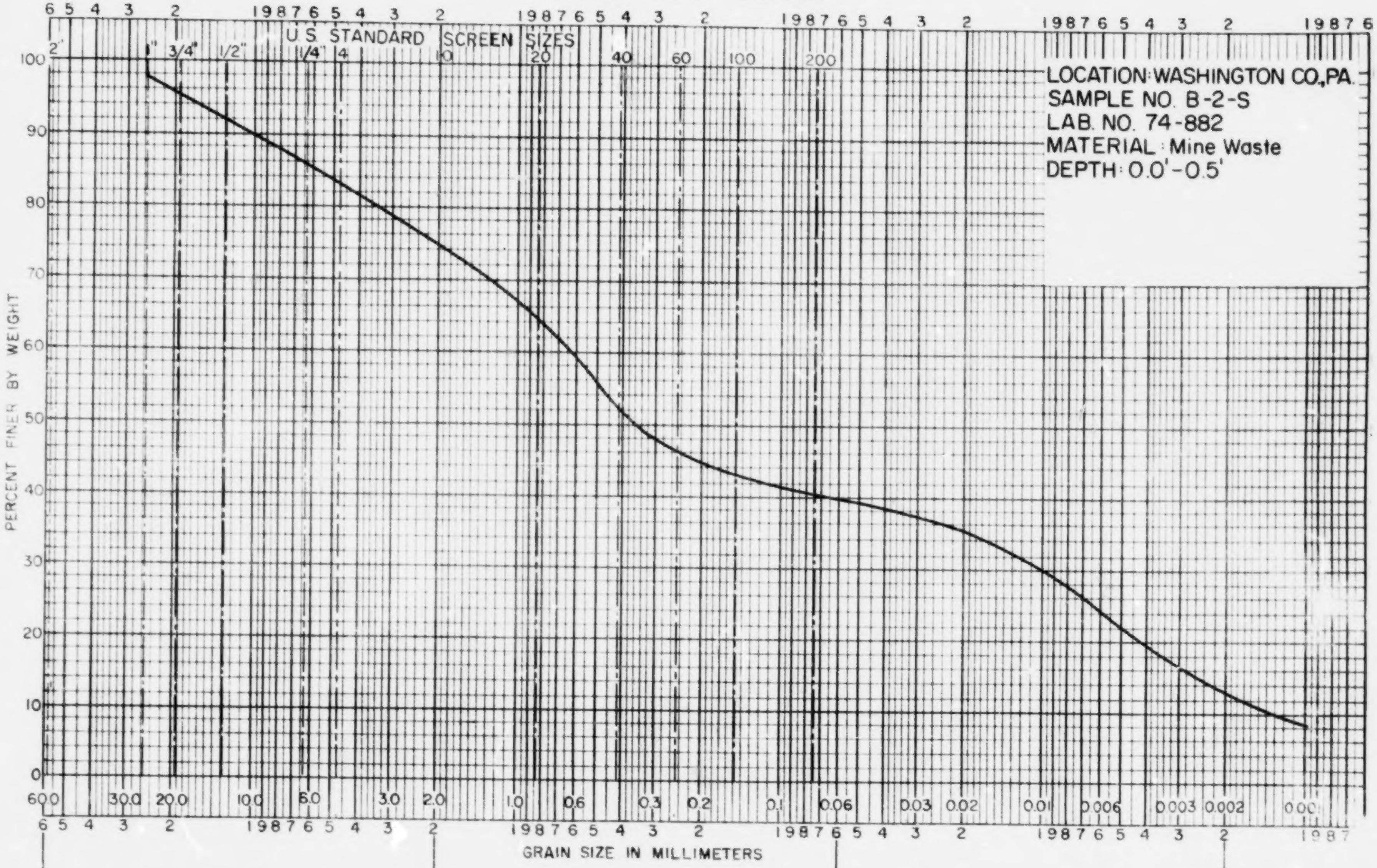
GRADATION CURVE



GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES ___			% SAND SIZES ___			% SILT SIZES ___			% CLAY SIZES ___

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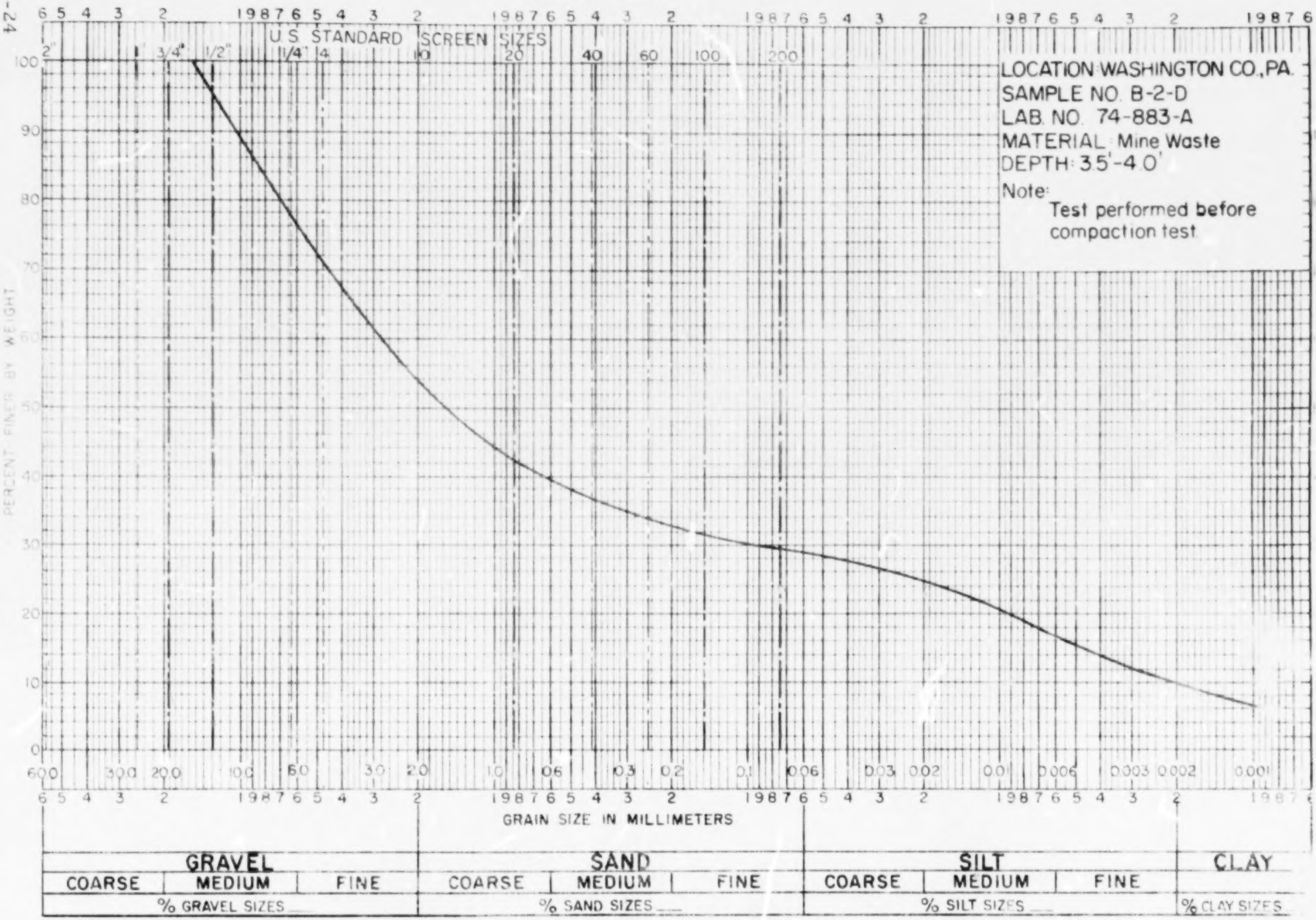
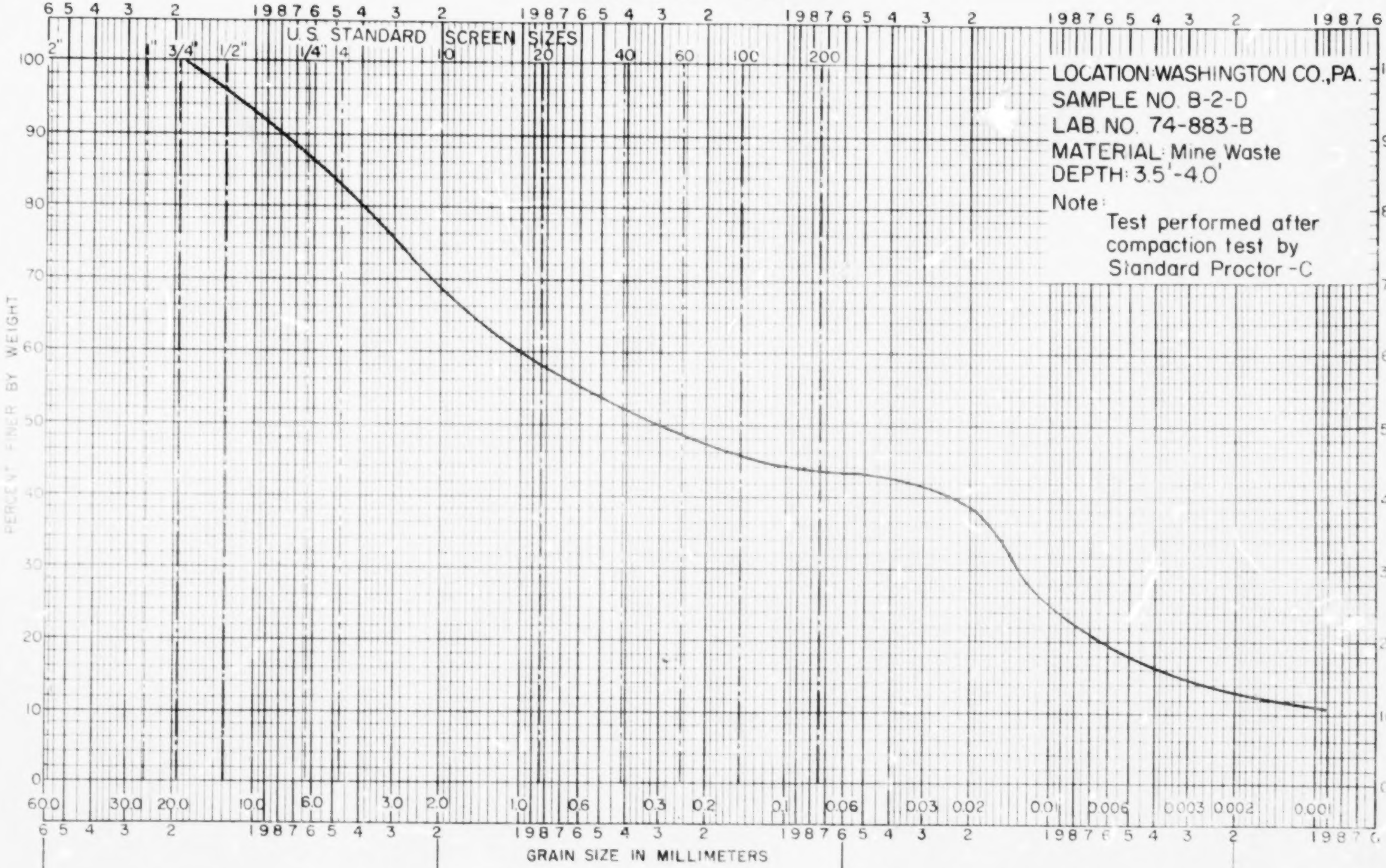
GRADATION CURVE



LOCATION: WASHINGTON CO., PA.
SAMPLE NO. B-2-D
LAB. NO. 74-883-A
MATERIAL: Mine Waste
DEPTH: 3.5'-4.0'
Note:
Test performed before compaction test

MICHAEL BAKER, JR., INC. Beaver, Pa. GEOTECHNICAL ENGINEERING DEPARTMENT

GRADATION CURVE



LOCATION: WASHINGTON CO., PA.
SAMPLE NO. B-2-D
LAB. NO. 74-883-B
MATERIAL: Mine Waste
DEPTH: 3.5'-4.0'
Note:
Test performed after
compaction test by
Standard Proctor -C

GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES ___			% SAND SIZES ___			% SILT SIZES ___			% CLAY SIZES ___

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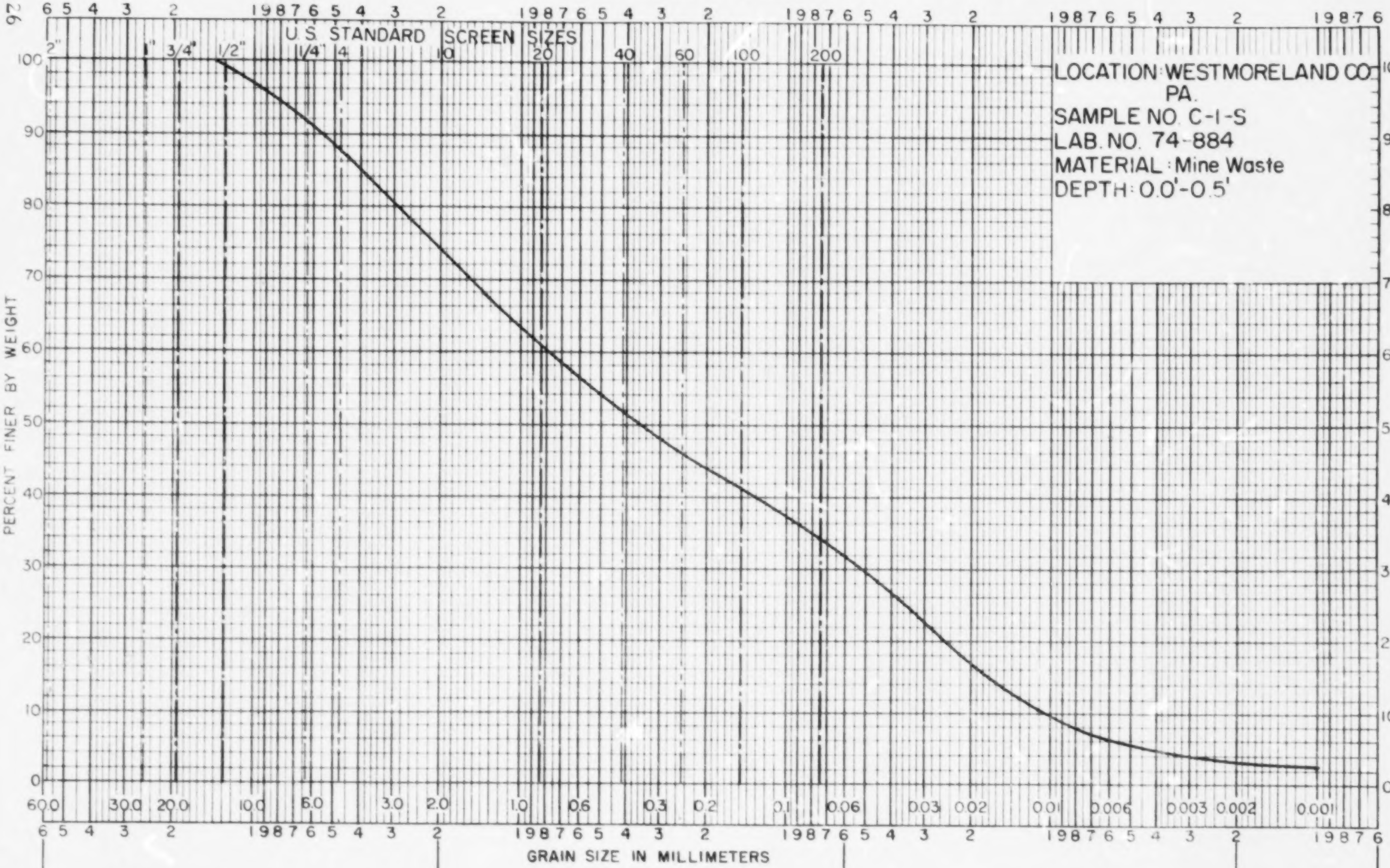
GRADATION CURVE

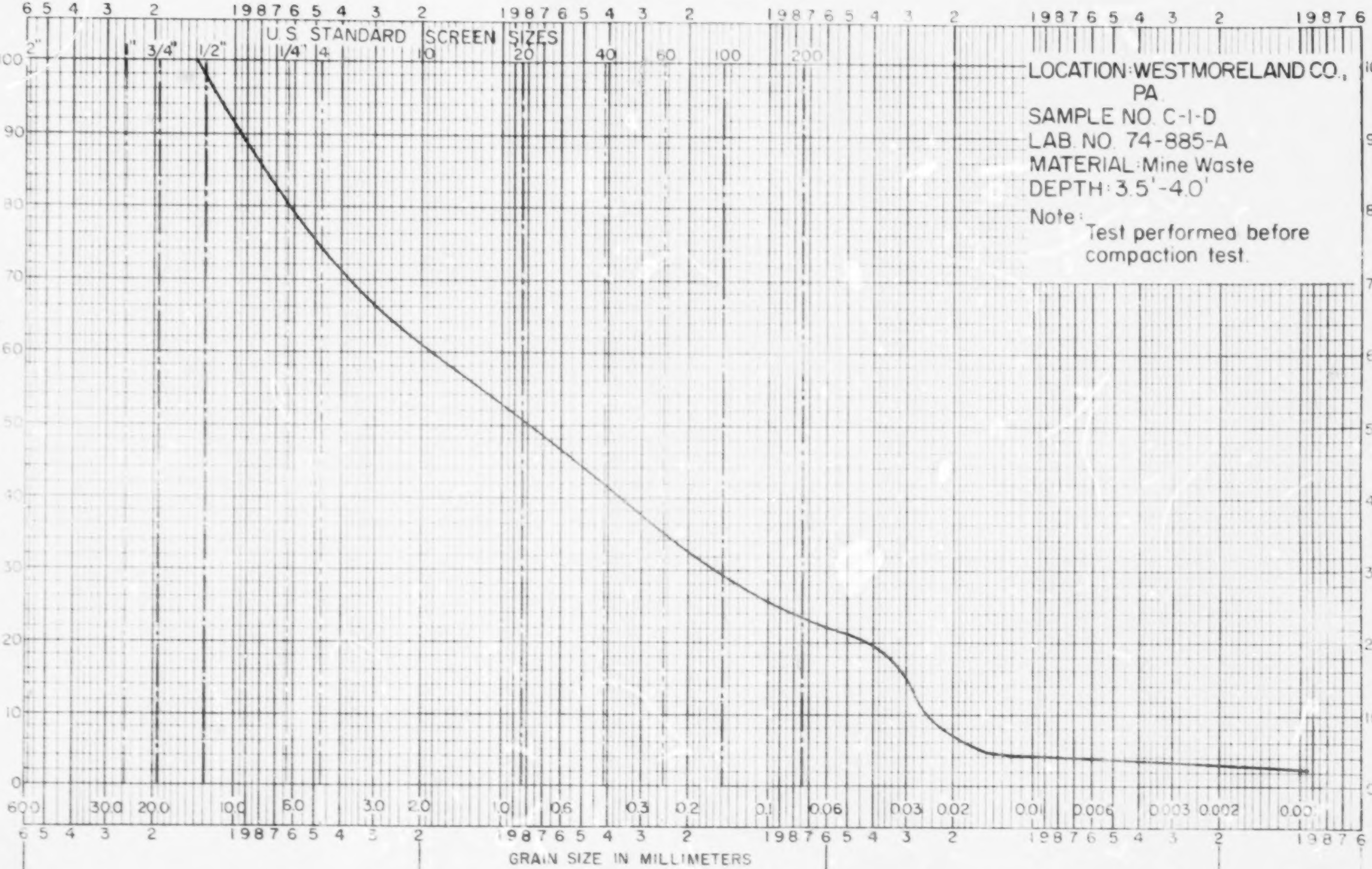


LOCATION: WESTMORELAND CO. PA.
SAMPLE NO. C-1-S
LAB. NO. 74-884
MATERIAL: Mine Waste
DEPTH: 0.0'-0.5'

GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES ___			% SAND SIZES ___			% SILT SIZES ___			% CLAY SIZES ___

'CHAEL BAKER, JR., INC. Beaver, Pa. GEOTECHNICAL ENGINEERING DEPARTMENT

GRADATION CURVE



LOCATION: WESTMORELAND CO., PA.
SAMPLE NO. C-1-D
LAB. NO. 74-885-A
MATERIAL: Mine Waste
DEPTH: 3.5'-4.0'
Note: Test performed before compaction test.

GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES ___			% SAND SIZES ___			% SILT SIZES ___			% CLAY SIZES ___

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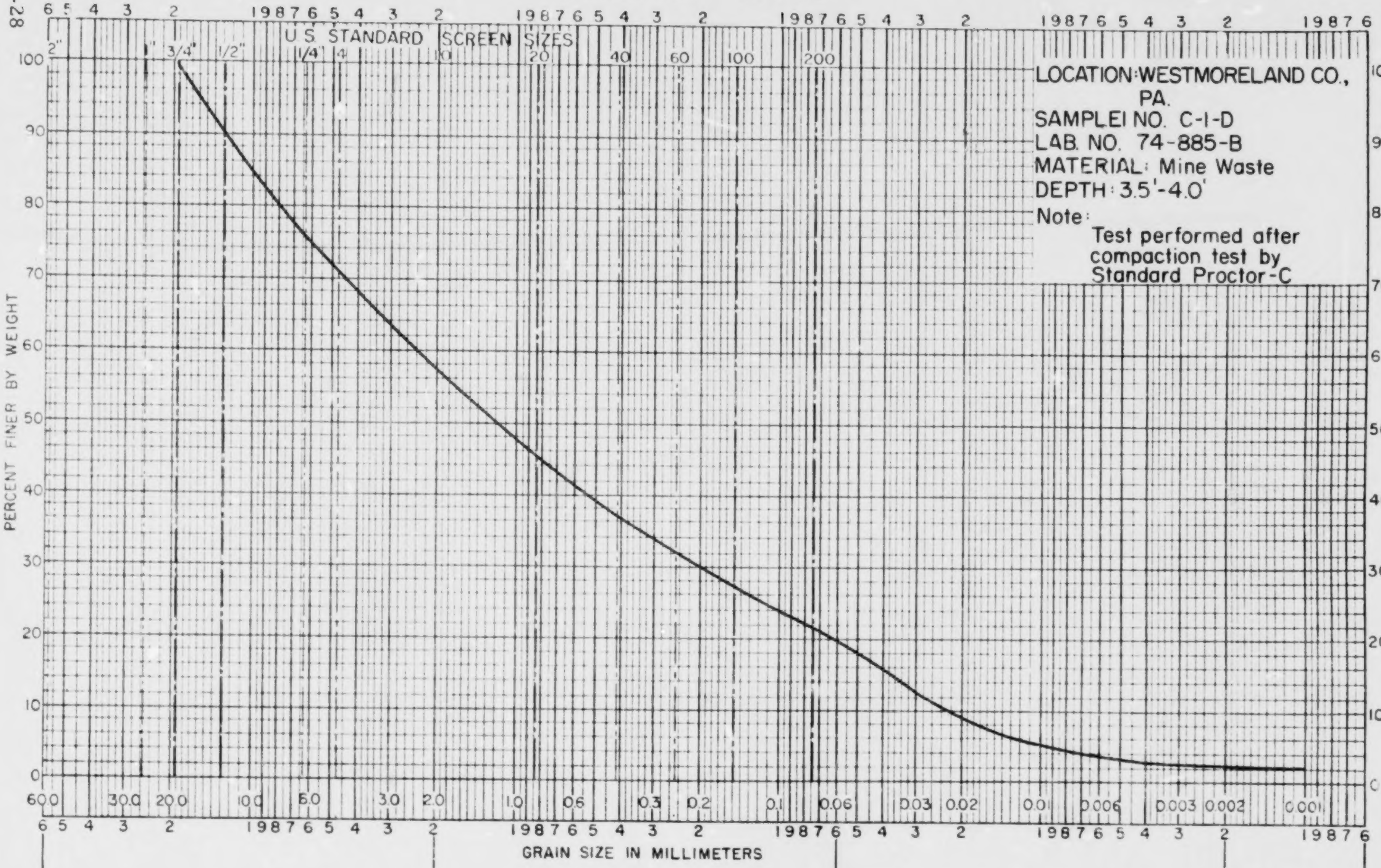
GRADATION CURVE



LOCATION: WESTMORELAND CO., PA.
SAMPLE NO. C-1-D
LAB. NO. 74-885-B
MATERIAL: Mine Waste
DEPTH: 3.5'-4.0'
Note:
Test performed after compaction test by Standard Proctor-C

GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES___			% SAND SIZES___			% SILT SIZES___			% CLAY SIZES___

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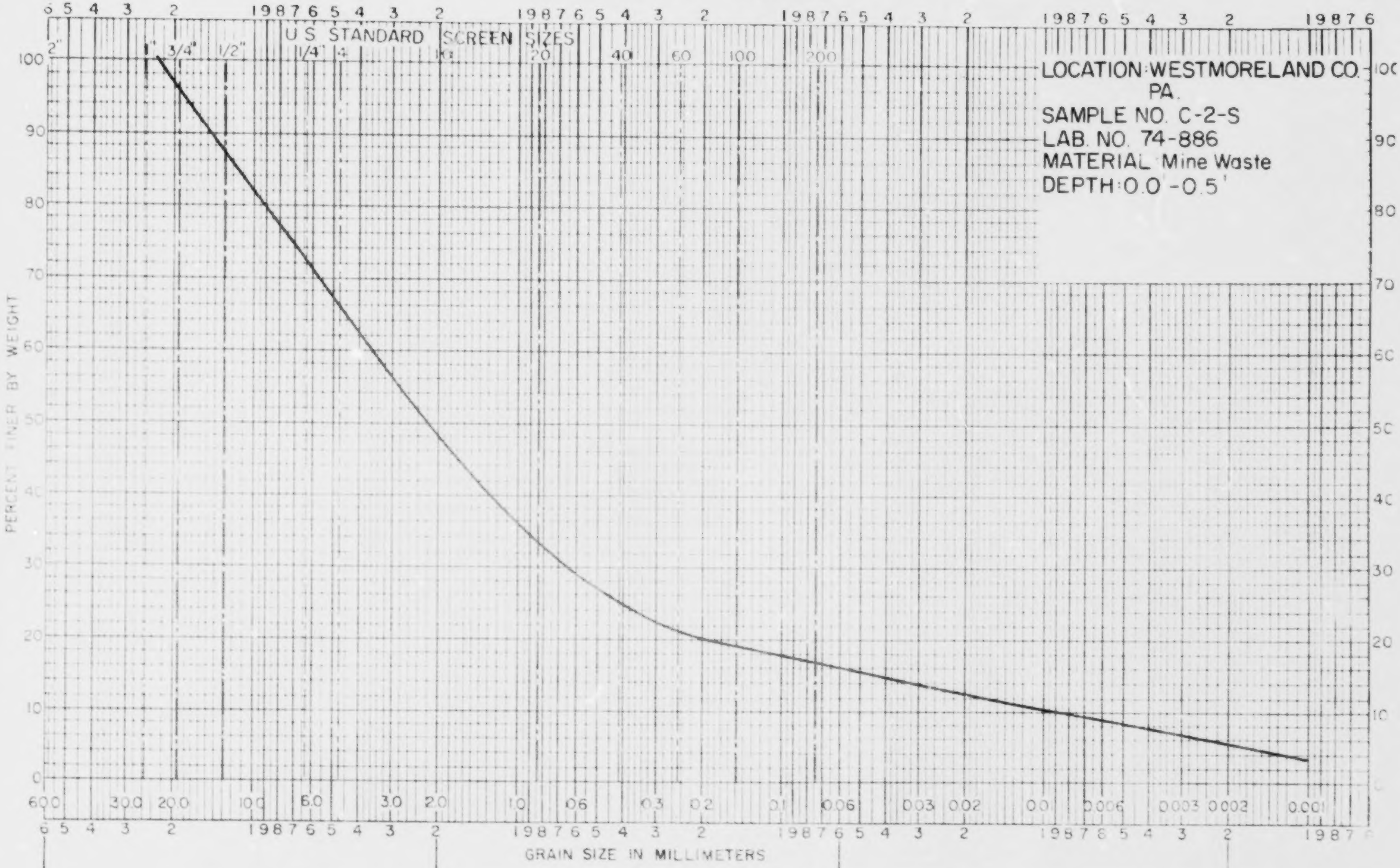
GRADATION CURVE



LOCATION: WESTMORELAND CO.
PA.
SAMPLE NO. C-2-S
LAB. NO. 74-886
MATERIAL: Mine Waste
DEPTH: 0.0 - 0.5'

GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES ___			% SAND SIZES ___			% SILT SIZES ___			% CLAY SIZES ___

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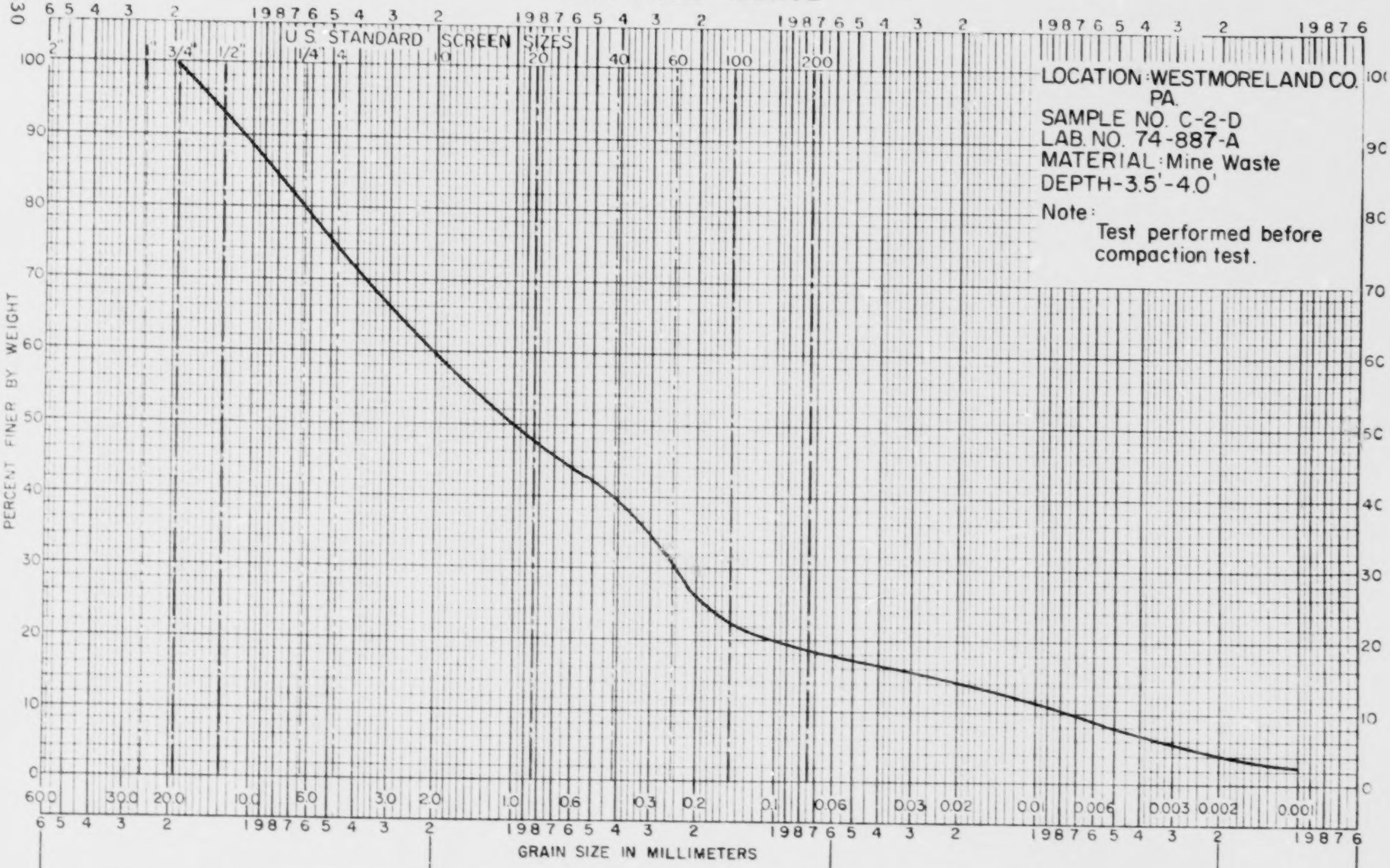
GRADATION CURVE



LOCATION: WESTMORELAND CO.
PA.
SAMPLE NO. C-2-D
LAB. NO. 74-887-A
MATERIAL: Mine Waste
DEPTH-3.5'-4.0'
Note:
Test performed before
compaction test.

GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES ___			% SAND SIZES ___			% SILT SIZES ___			% CLAY SIZES ___

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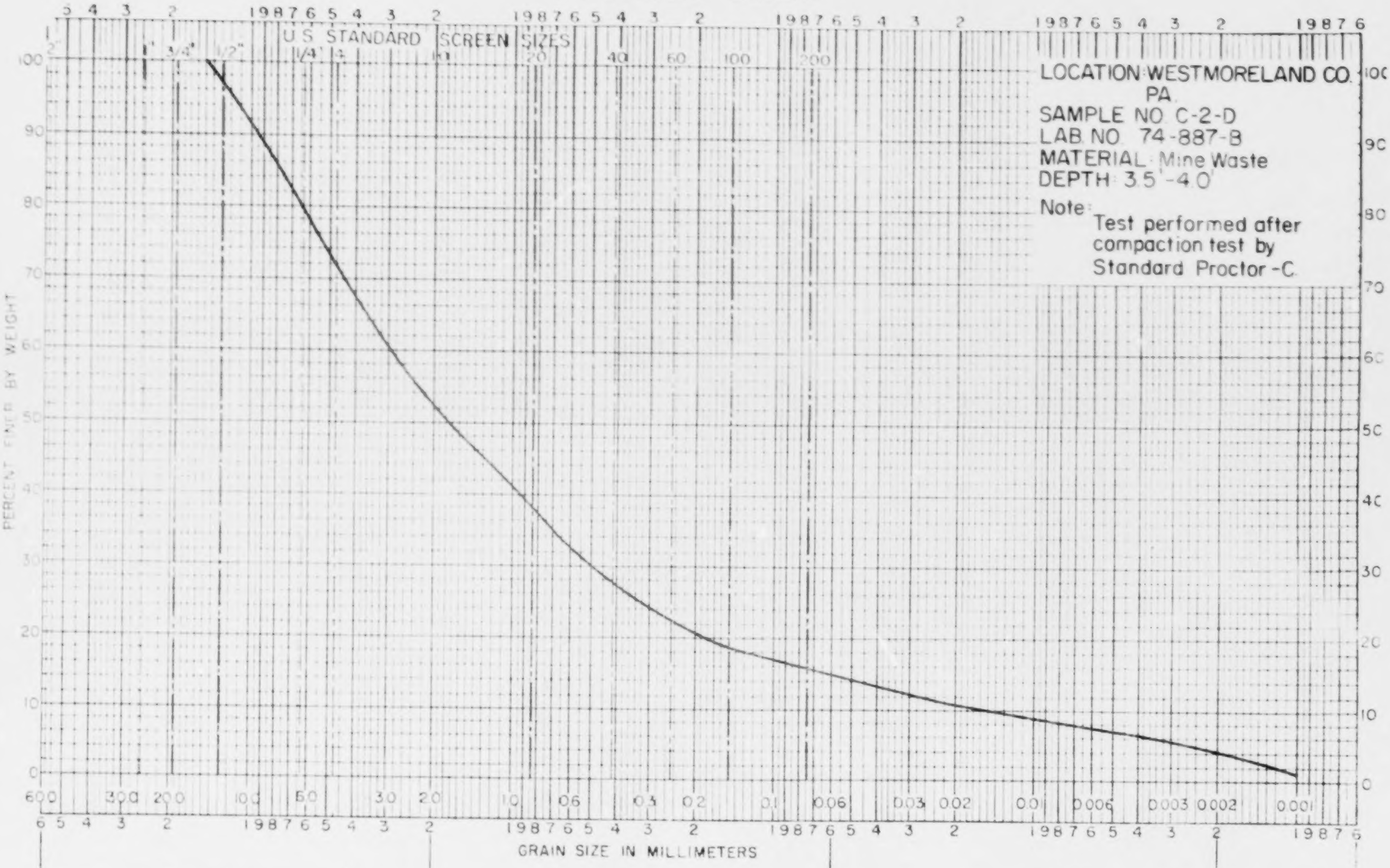
GRADATION CURVE



LOCATION: WESTMORELAND CO.
PA.
SAMPLE NO. C-2-D
LAB NO. 74-887-B
MATERIAL: Mine Waste
DEPTH: 3.5'-4.0'
Note:
Test performed after
compaction test by
Standard Proctor -C.

GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES ___			% SAND SIZES ___			% SILT SIZES			% CLAY SIZES ___

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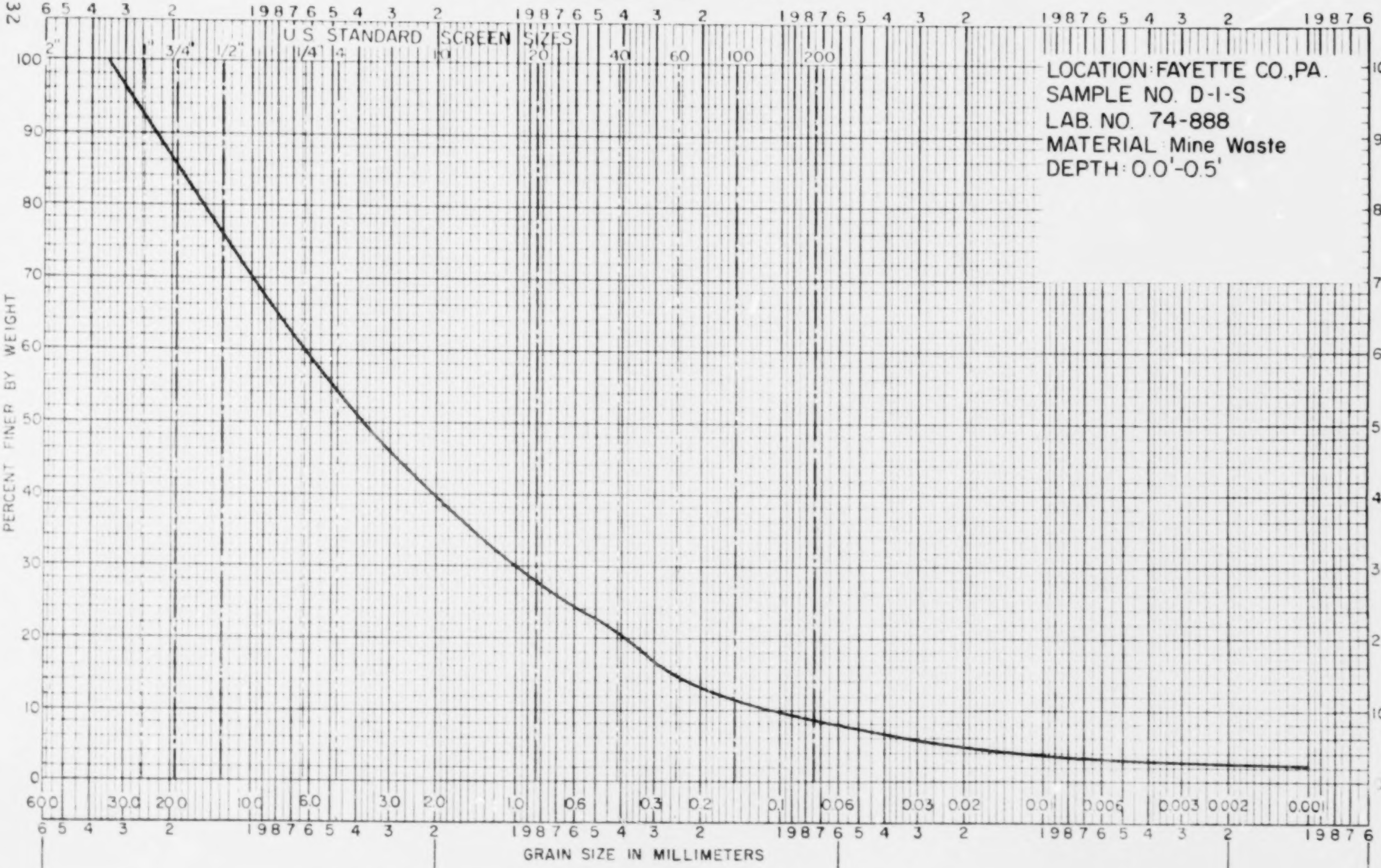
GRADATION CURVE



GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES ___			% SAND SIZES ___			% SILT SIZES ___			% CLAY SIZES ___

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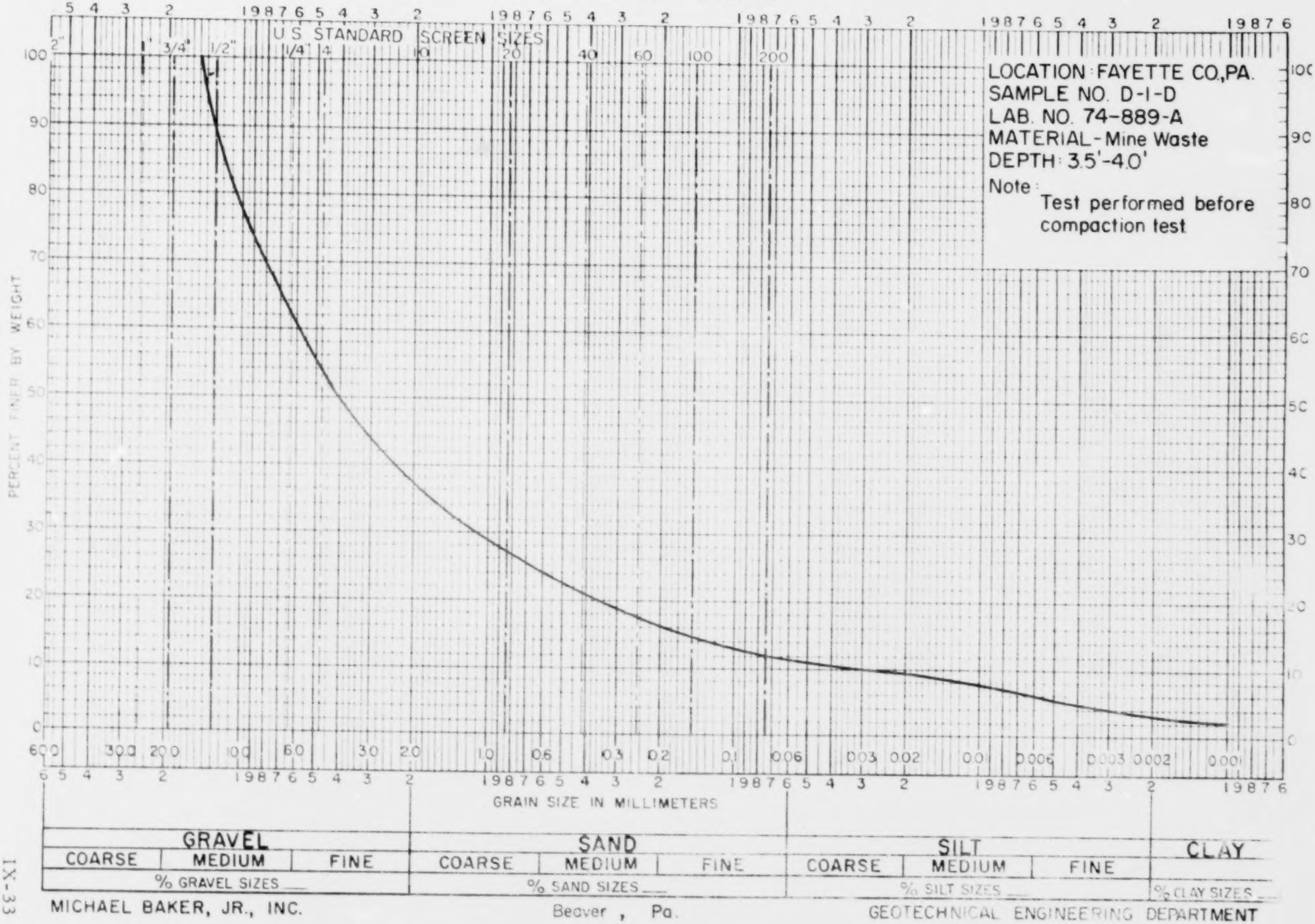
GRADATION CURVE



LOCATION: FAYETTE CO, PA.
SAMPLE NO. D-1-D
LAB. NO. 74-889-A
MATERIAL - Mine Waste
DEPTH: 3.5'-4.0'
Note:
Test performed before compaction test

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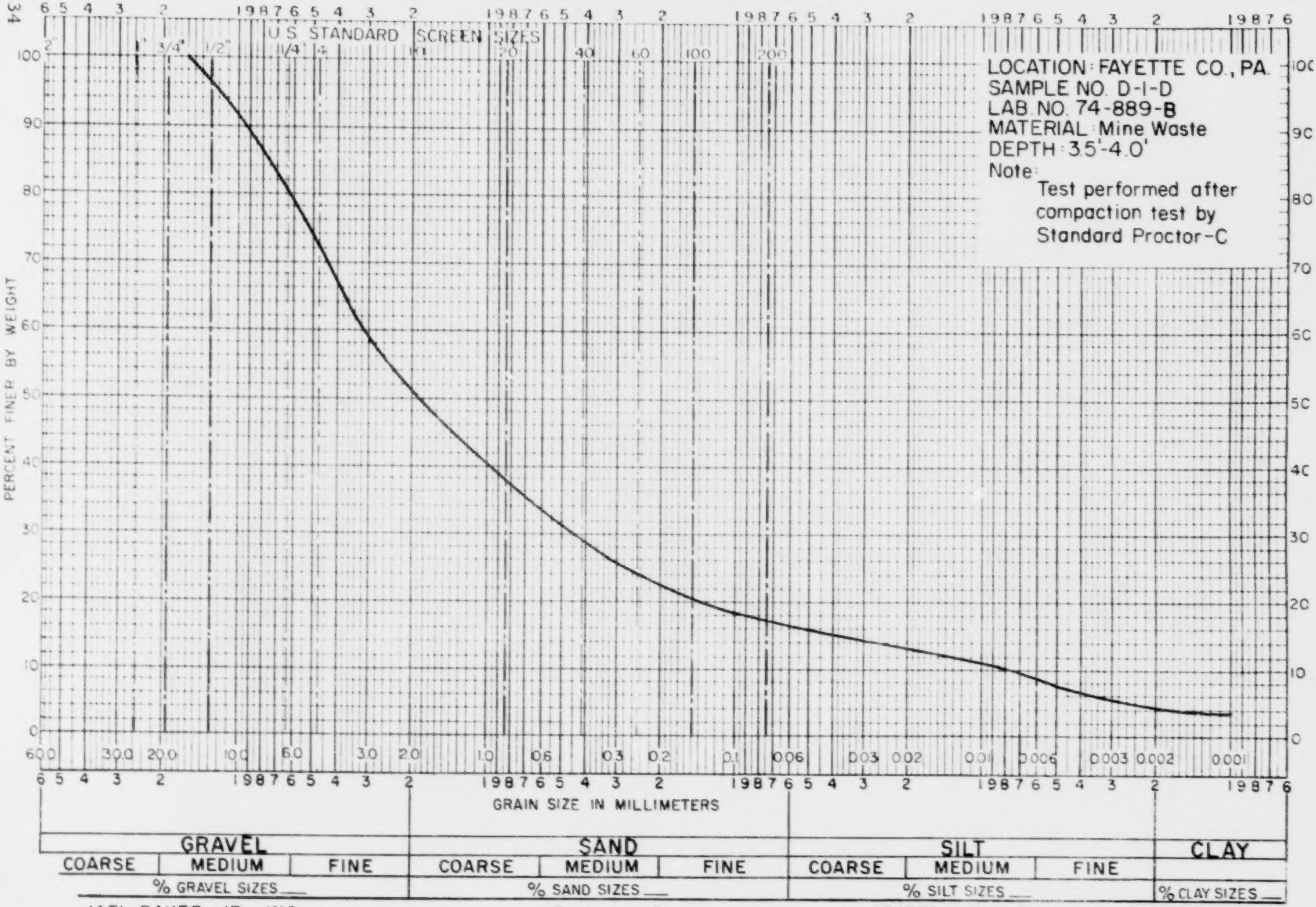
GEOTECHNICAL ENGINEERING DEPARTMENT

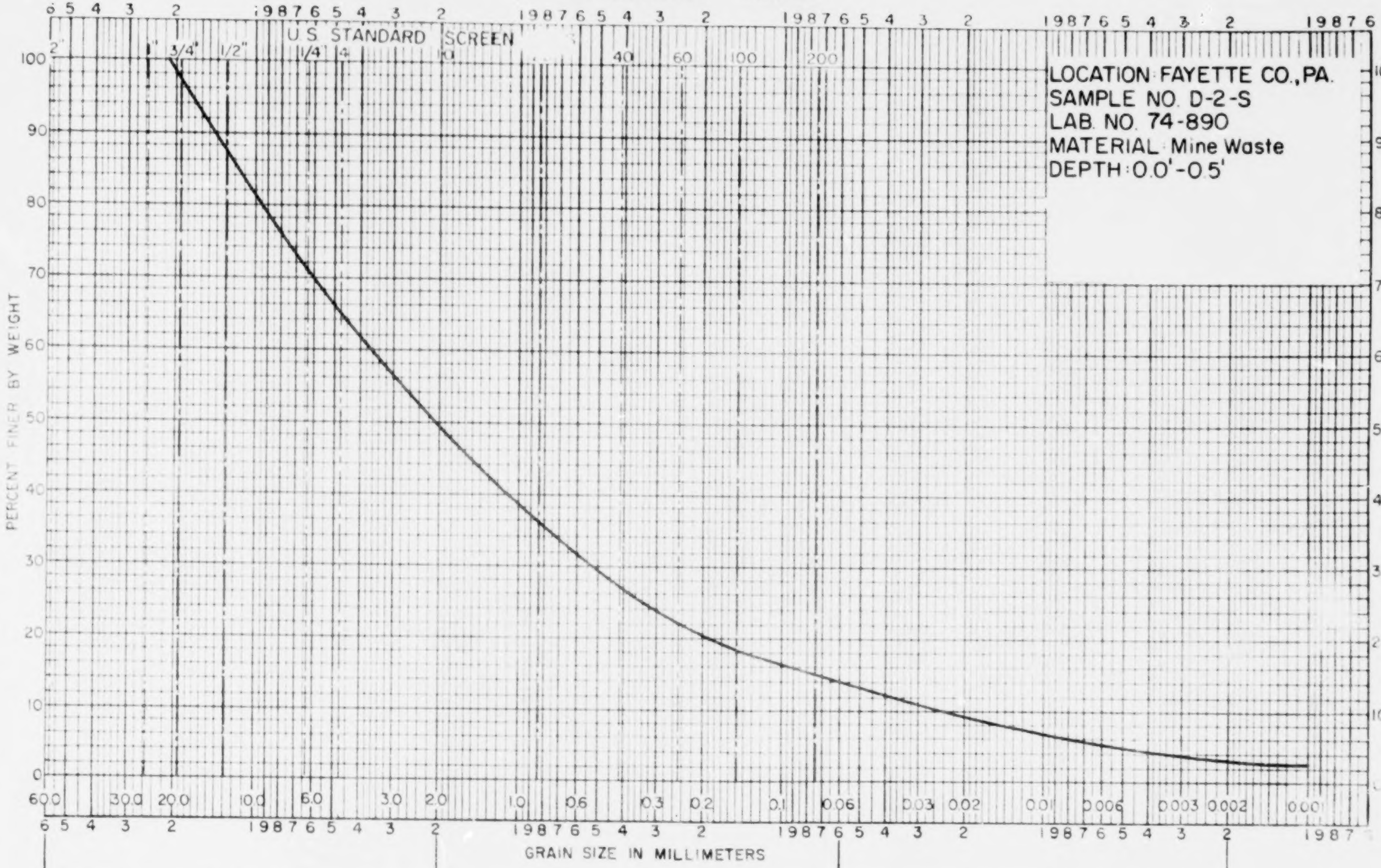
GRADATION CURVE



LOCATION: FAYETTE CO., PA.
SAMPLE NO. D-I-D
LAB. NO. 74-889-B
MATERIAL: Mine Waste
DEPTH: 3.5'-4.0'
Note:
Test performed after compaction test by Standard Proctor-C

'AEL BAKER, JR., INC. Beaver, Pa. GEOTECHNICAL ENGINEERING DEPARTMENT

GRADATION CURVE



GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES ___			% SAND SIZES ___			% SILT SIZES ___			% CLAY SIZES ___

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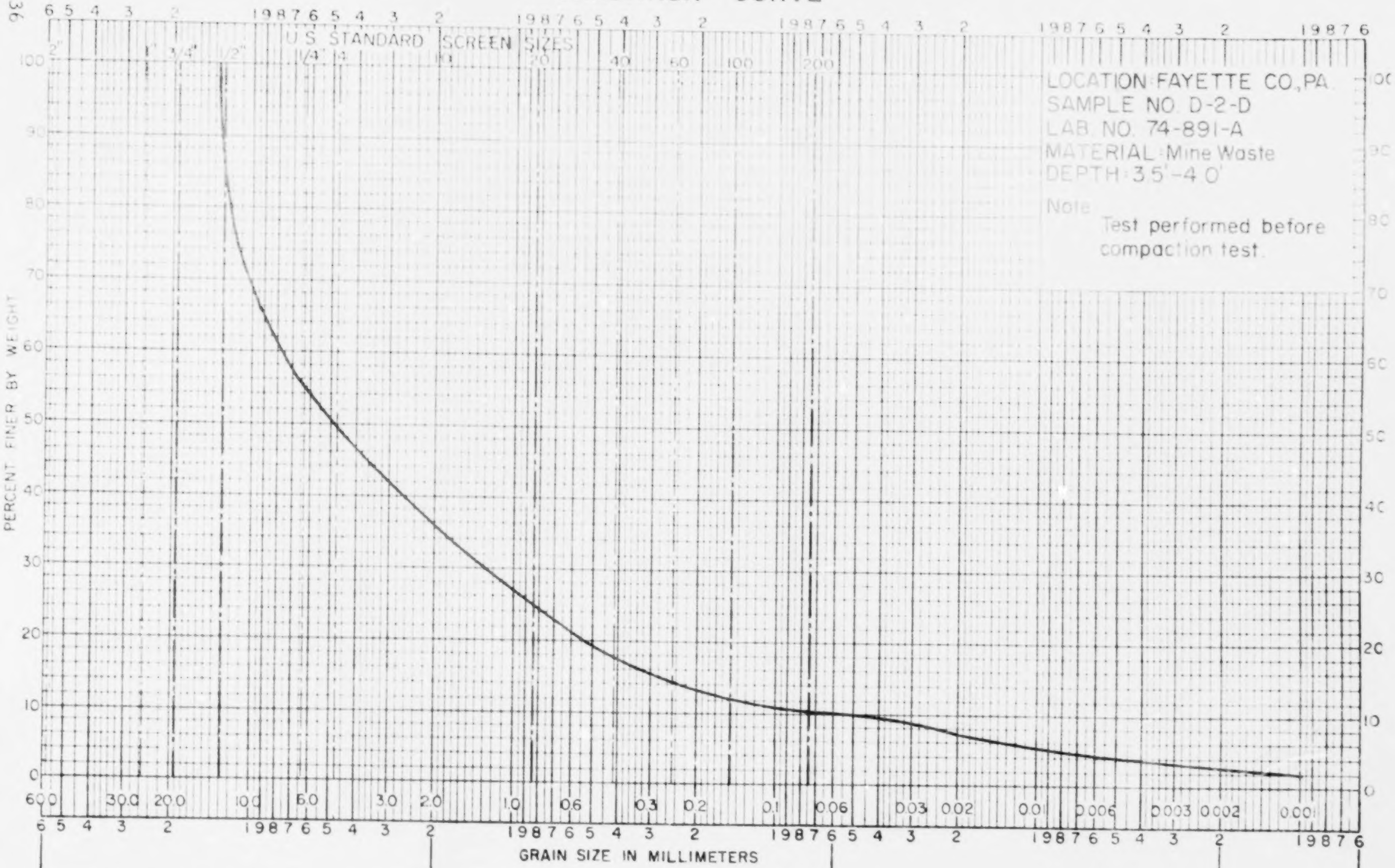
GRADATION CURVE



LOCATION: FAYETTE CO., PA.
SAMPLE NO. D-2-D
LAB. NO. 74-891-A
MATERIAL: Mine Waste
DEPTH: 3.5'-4.0'
Note: Test performed before compaction test.

GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES ___			% SAND SIZES ___			% SILT SIZES ___			% CLAY SIZES ___

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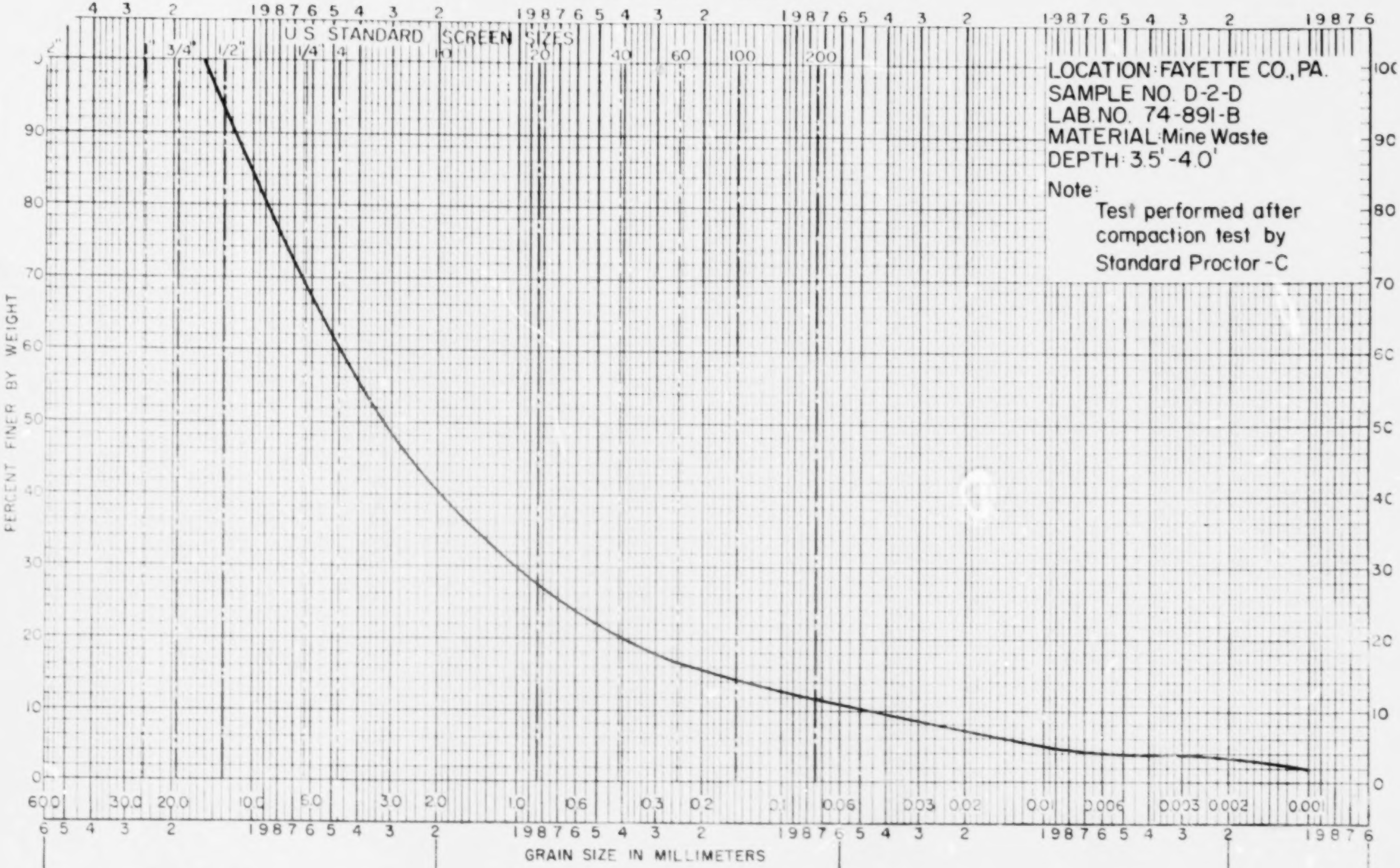
GRADATION CURVE



LOCATION: FAYETTE CO., PA.
SAMPLE NO. D-2-D
LAB. NO. 74-891-B
MATERIAL: Mine Waste
DEPTH: 3.5'-4.0'
Note:
Test performed after compaction test by Standard Proctor-C

GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES ___			% SAND SIZES ___			% SILT SIZES ___			% CLAY SIZES ___

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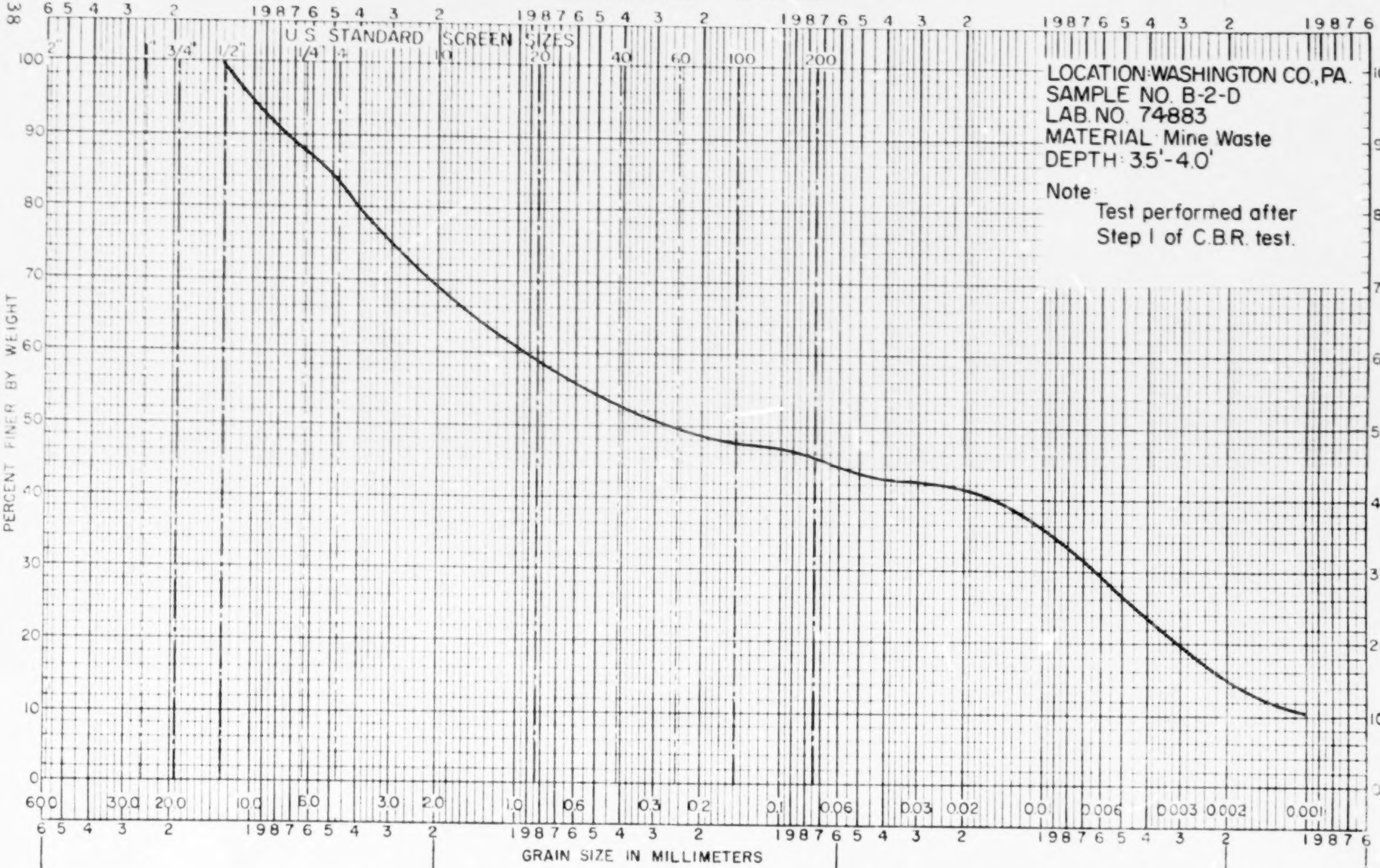
GRADATION CURVE



LOCATION: WASHINGTON CO., PA.
SAMPLE NO. B-2-D
LAB. NO. 74883
MATERIAL: Mine Waste
DEPTH: 3.5'-4.0'

Note:
Test performed after
Step I of C.B.R. test.

GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES ___			% SAND SIZES ___			% SILT SIZES ___			% CLAY SIZES ___

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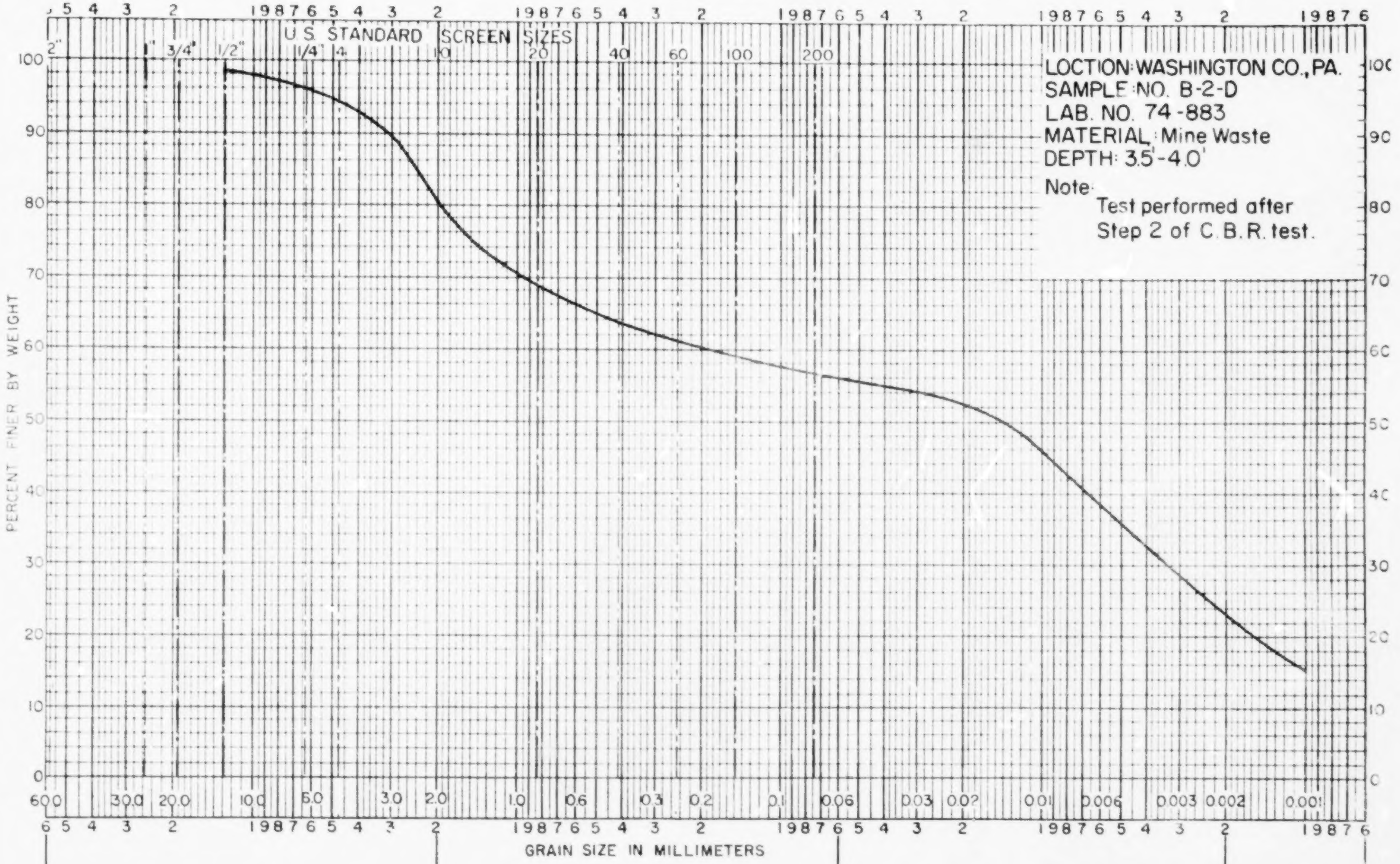
GRADATION CURVE



LOCTION: WASHINGTON CO., PA.
SAMPLE NO. B-2-D
LAB. NO. 74-883
MATERIAL: Mine Waste
DEPTH: 3.5'-4.0'
Note:
Test performed after
Step 2 of C.B.R. test.

GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES ___			% SAND SIZES ___			% SILT SIZES ___			% CLAY SIZES ___

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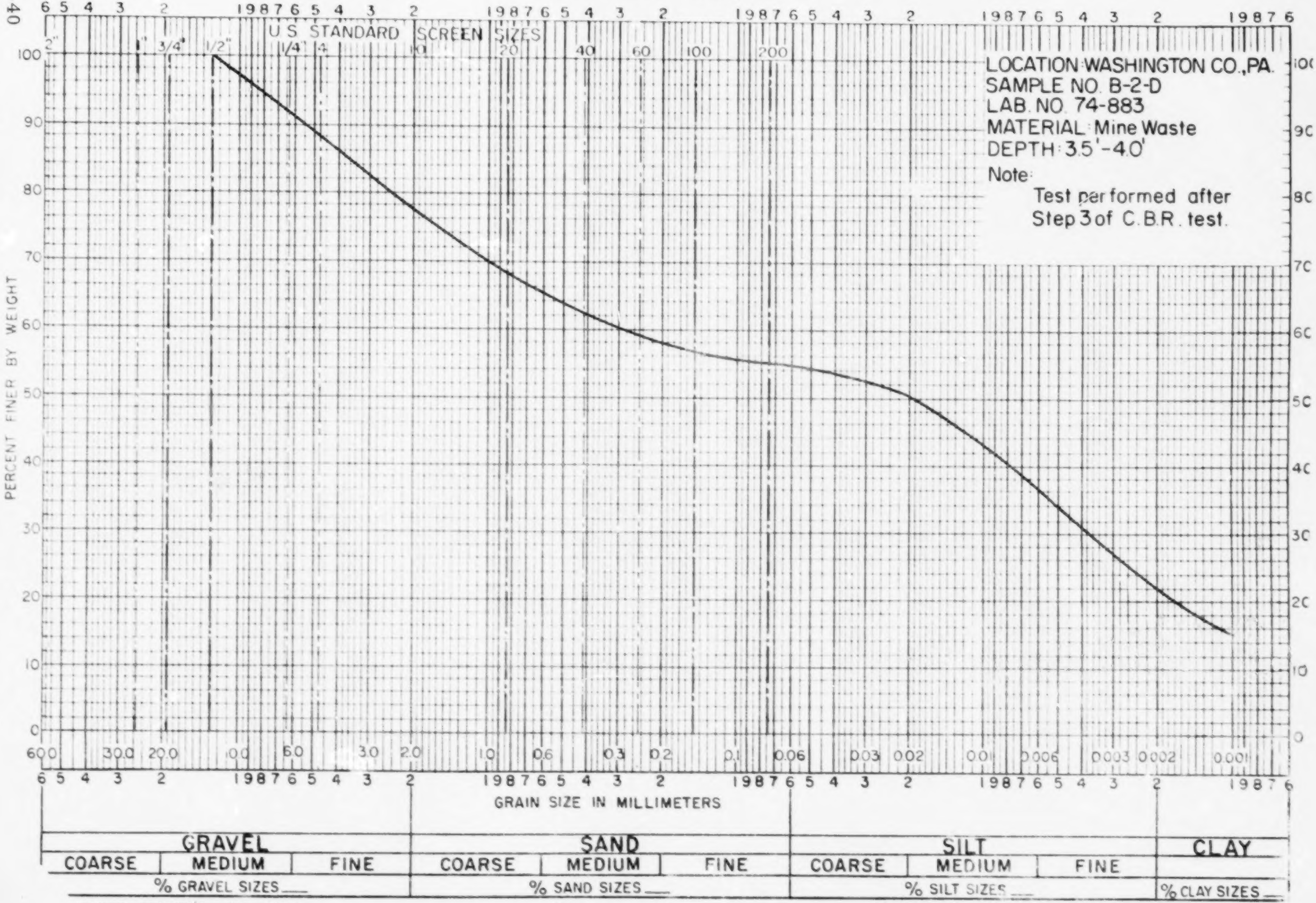
GRADATION CURVE



LOCATION: WASHINGTON CO., PA.
SAMPLE NO. B-2-D
LAB. NO. 74-883
MATERIAL: Mine Waste
DEPTH: 3.5'-4.0'
Note:
Test performed after
Step 3 of C.B.R. test.

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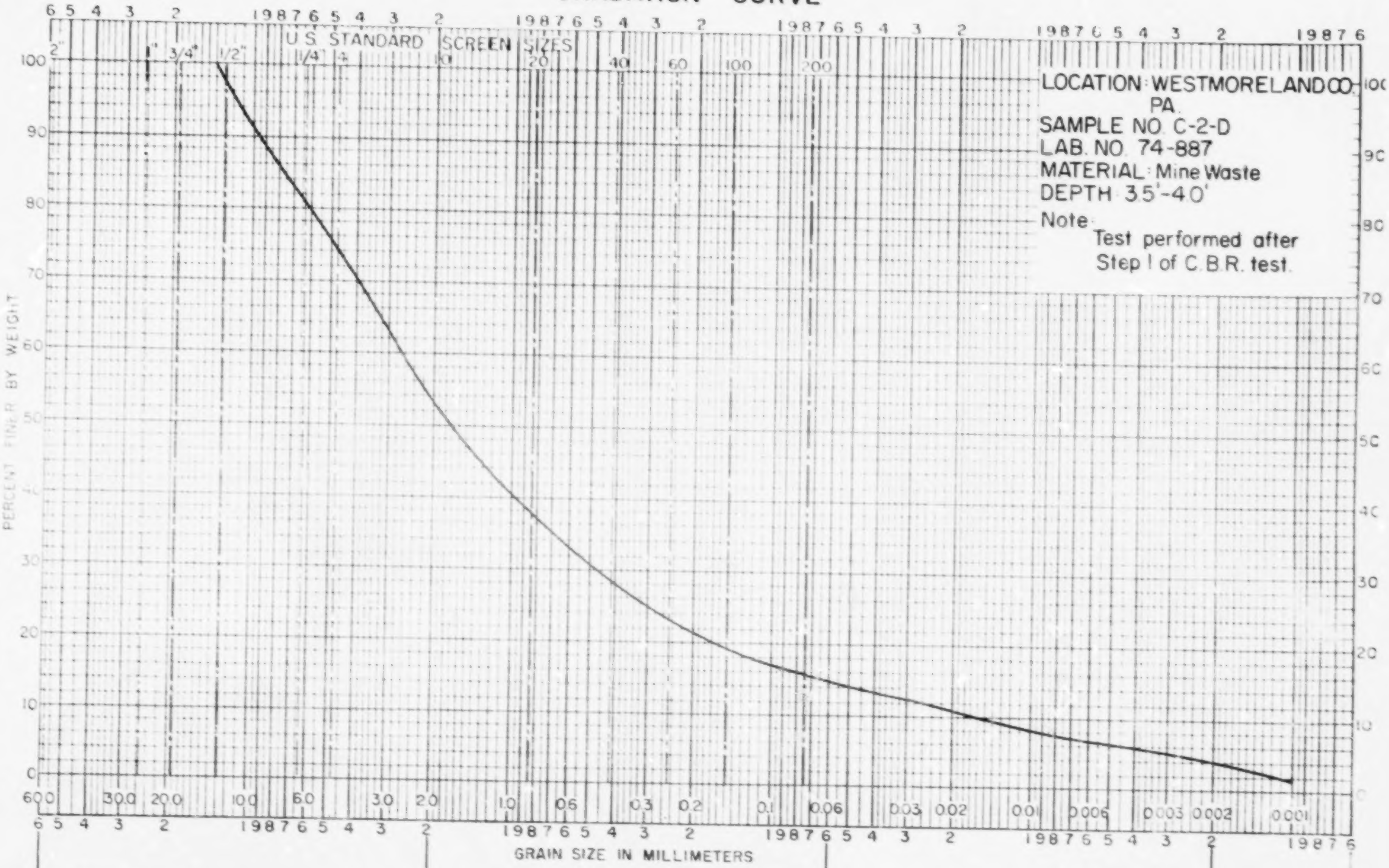
GRADATION CURVE



LOCATION: WESTMORELAND CO.
PA.
SAMPLE NO. C-2-D
LAB. NO. 74-887
MATERIAL: Mine Waste
DEPTH 3.5'-4.0'
Note:
Test performed after
Step I of C.B.R. test.

GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES___			% SAND SIZES___			% SILT SIZES___			% CLAY SIZES___

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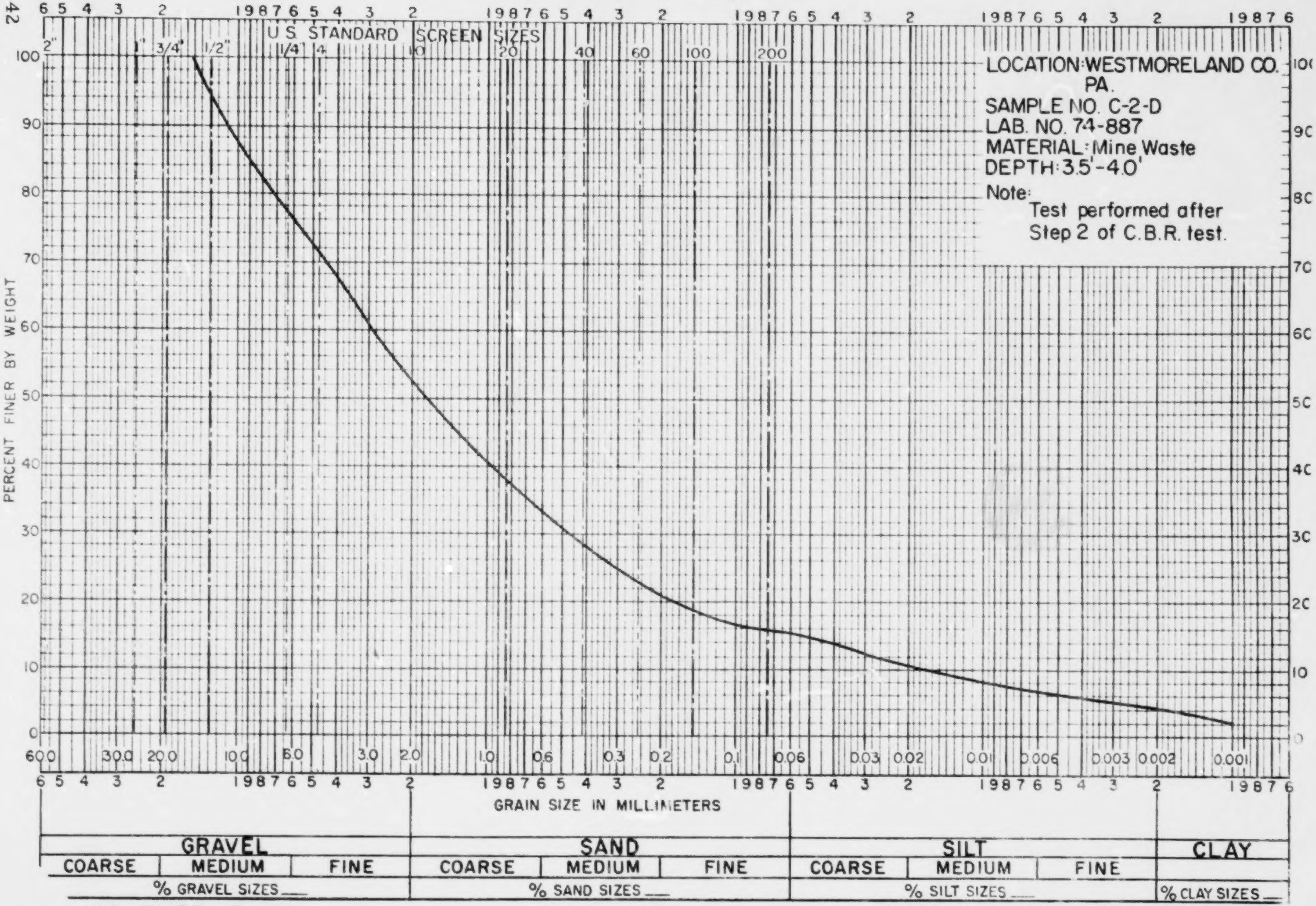
GRADATION CURVE



LOCATION: WESTMORELAND CO.
PA.
SAMPLE NO. C-2-D
LAB. NO. 74-887
MATERIAL: Mine Waste
DEPTH: 3.5'-4.0'
Note:
Test performed after
Step 2 of C.B.R. test.

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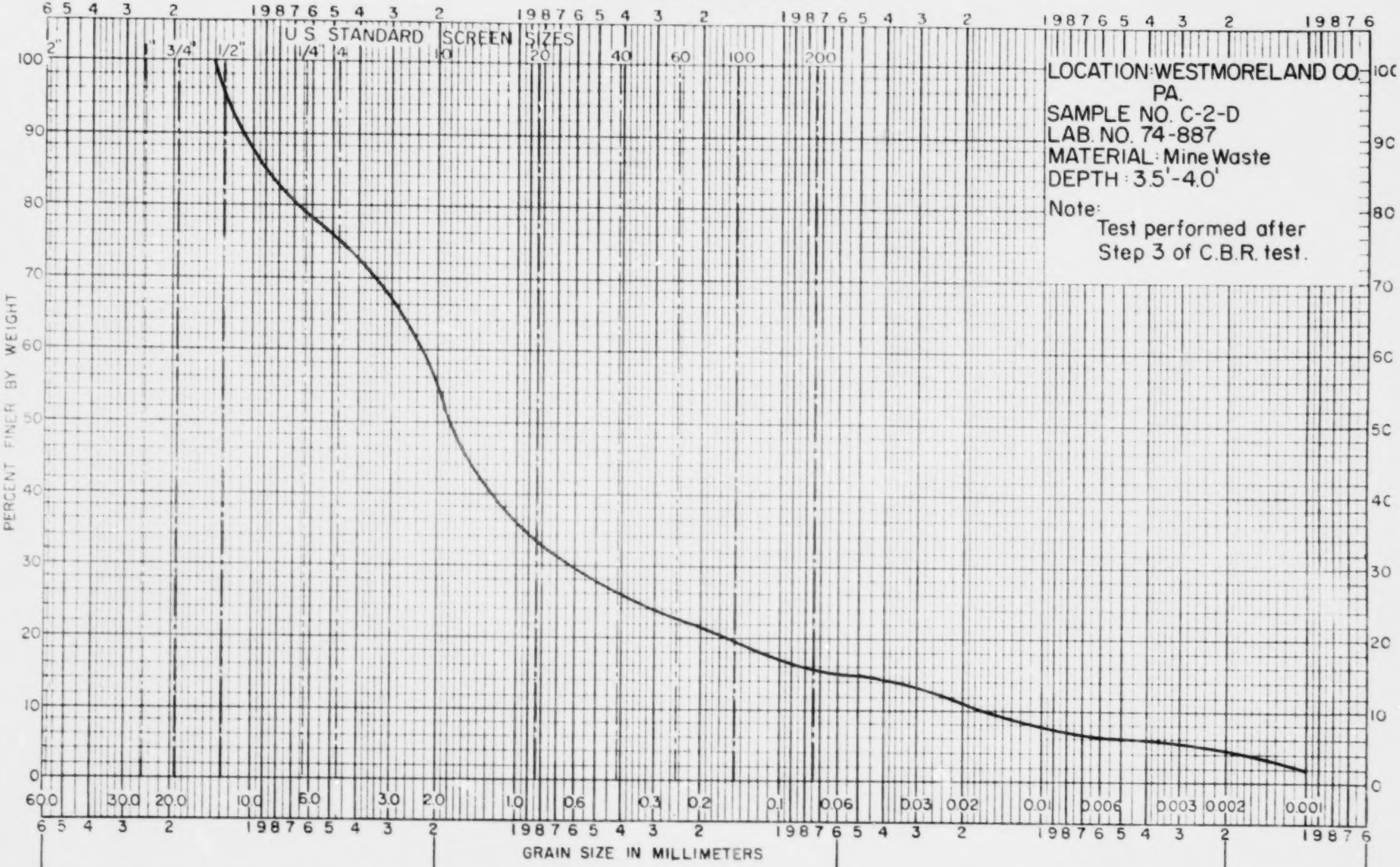
GRADATION CURVE



LOCATION: WESTMORELAND CO.
PA.
SAMPLE NO. C-2-D
LAB. NO. 74-887
MATERIAL: Mine Waste
DEPTH : 3.5'-4.0'

Note:
Test performed after
Step 3 of C.B.R. test.

GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES ___			% SAND SIZES ___			% SILT SIZES ___			% CLAY SIZES ___

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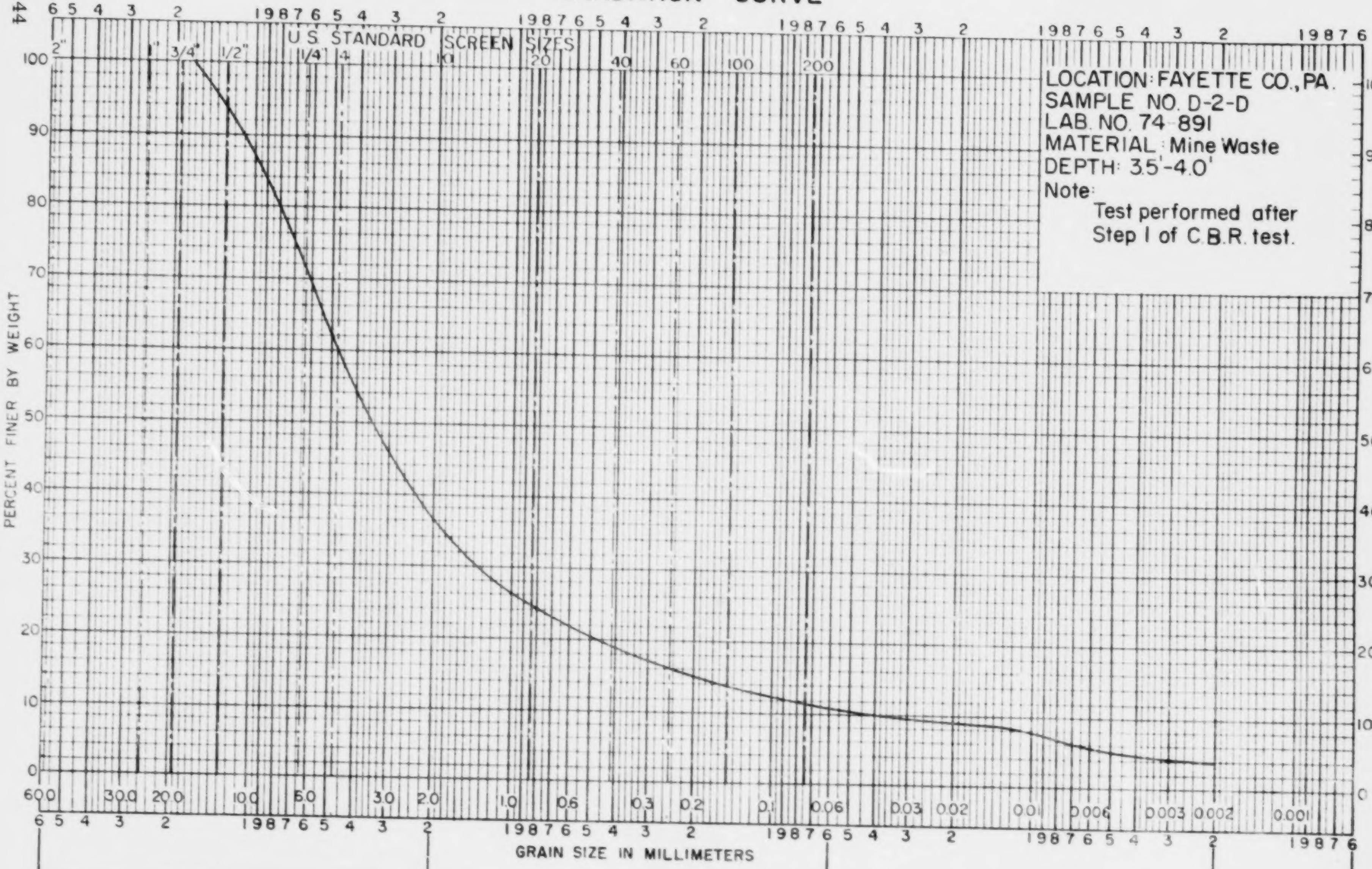
GRADATION CURVE



LOCATION: FAYETTE CO., PA.
SAMPLE NO. D-2-D
LAB. NO. 74-891
MATERIAL: Mine Waste
DEPTH: 3.5'-4.0'
Note:
Test performed after
Step I of C.B.R. test.

GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES ___			% SAND SIZES ___			% SILT SIZES ___			% CLAY SIZES ___

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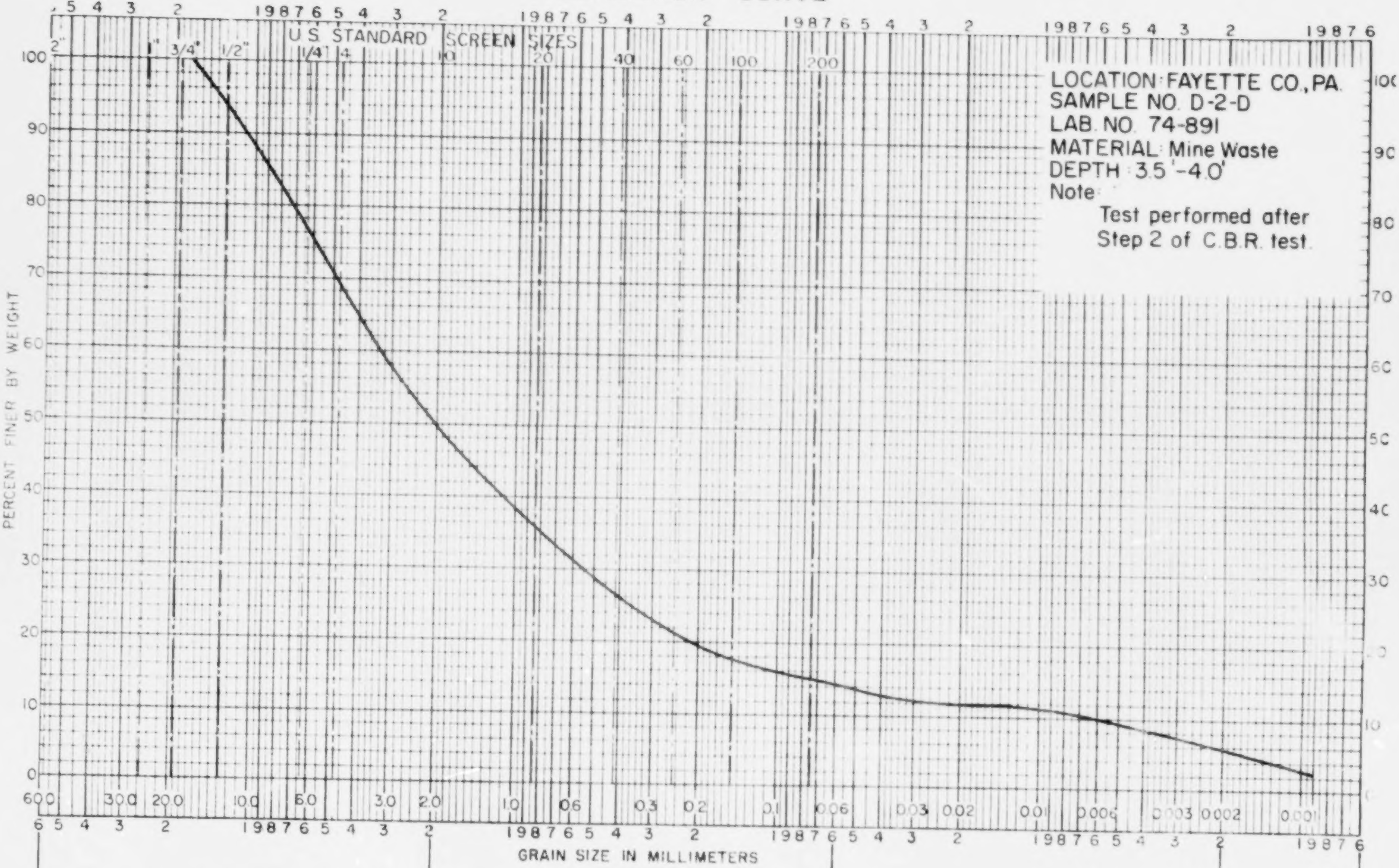
Beaver, Pa.
GEOTECHNICAL ENGINEERING DEPARTMENT

GRADATION CURVE



LOCATION: FAYETTE CO., PA.
SAMPLE NO. D-2-D
LAB. NO. 74-891
MATERIAL: Mine Waste
DEPTH: 3.5'-4.0'
Note:
Test performed after
Step 2 of C.B.R. test.

GRAVEL			SAND			SILT			CLAY
COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	
% GRAVEL SIZES ___			% SAND SIZES ___			% SILT SIZES ___			% CLAY SIZES ___

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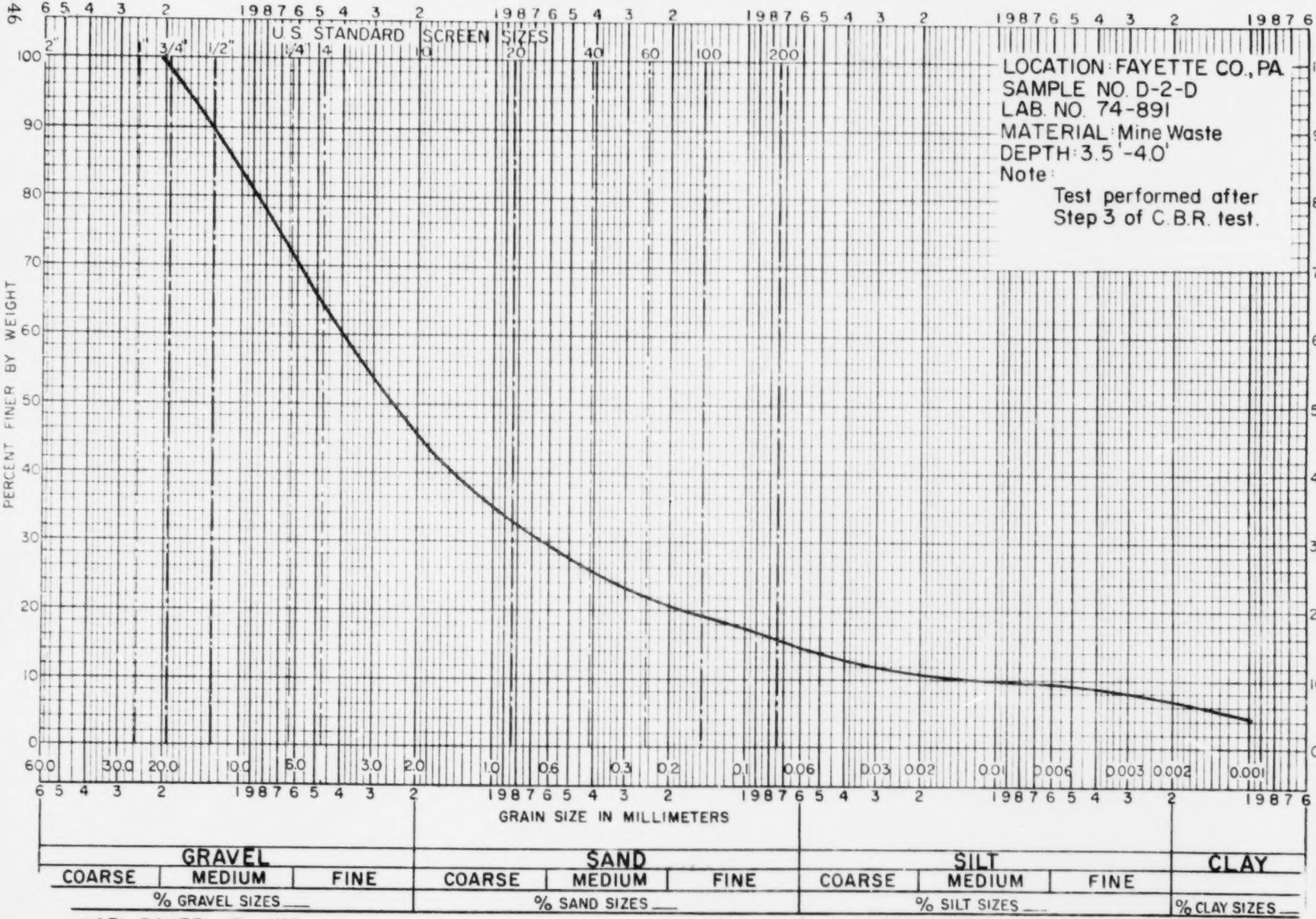
GRADATION CURVE



LOCATION: FAYETTE CO., PA
SAMPLE NO. D-2-D
LAB. NO. 74-891
MATERIAL: Mine Waste
DEPTH: 3.5'-4.0'
Note:
Test performed after
Step 3 of C.B.R. test.

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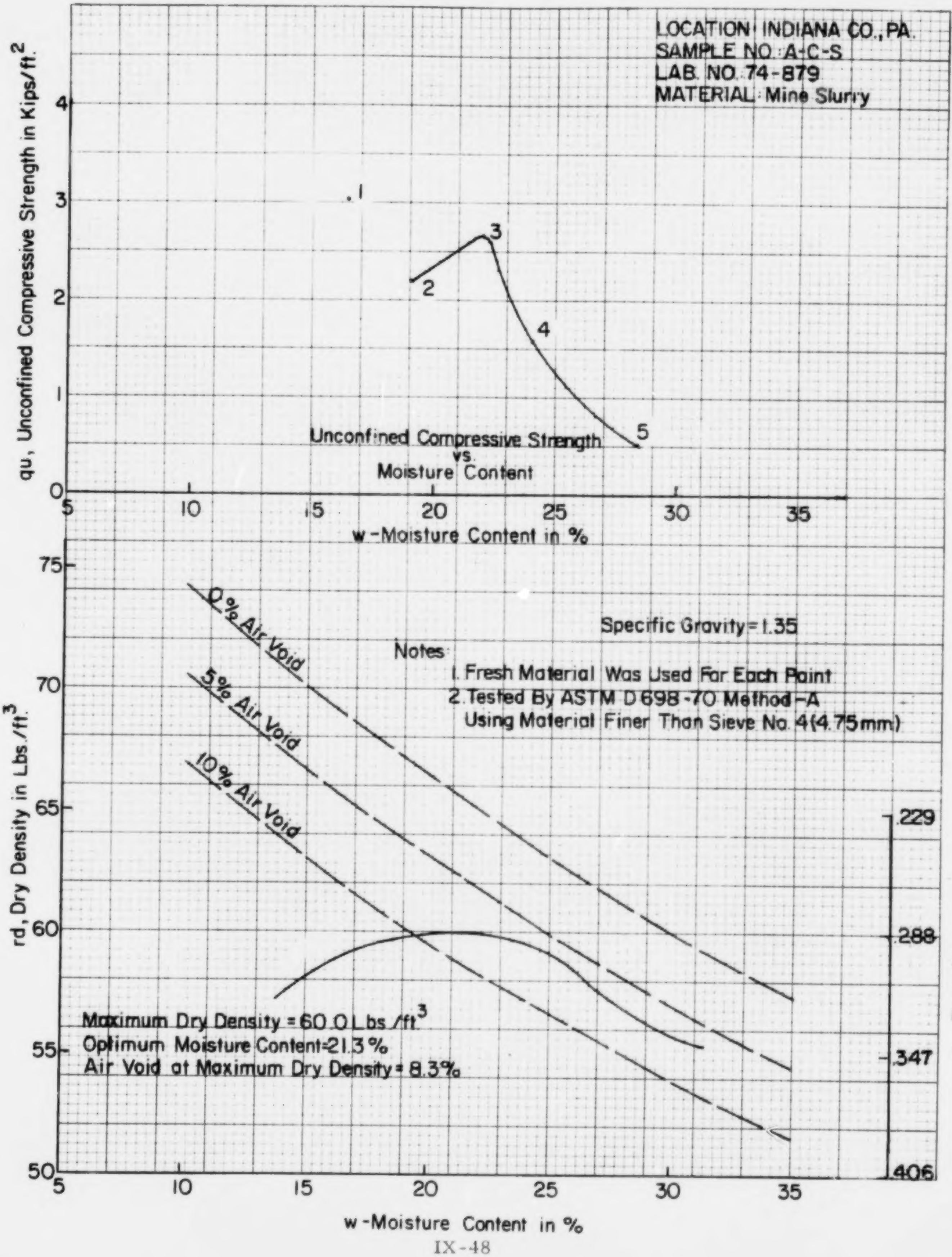
EXHIBIT B

Moisture Density Relationship
and
Unconfined Compressive Strength



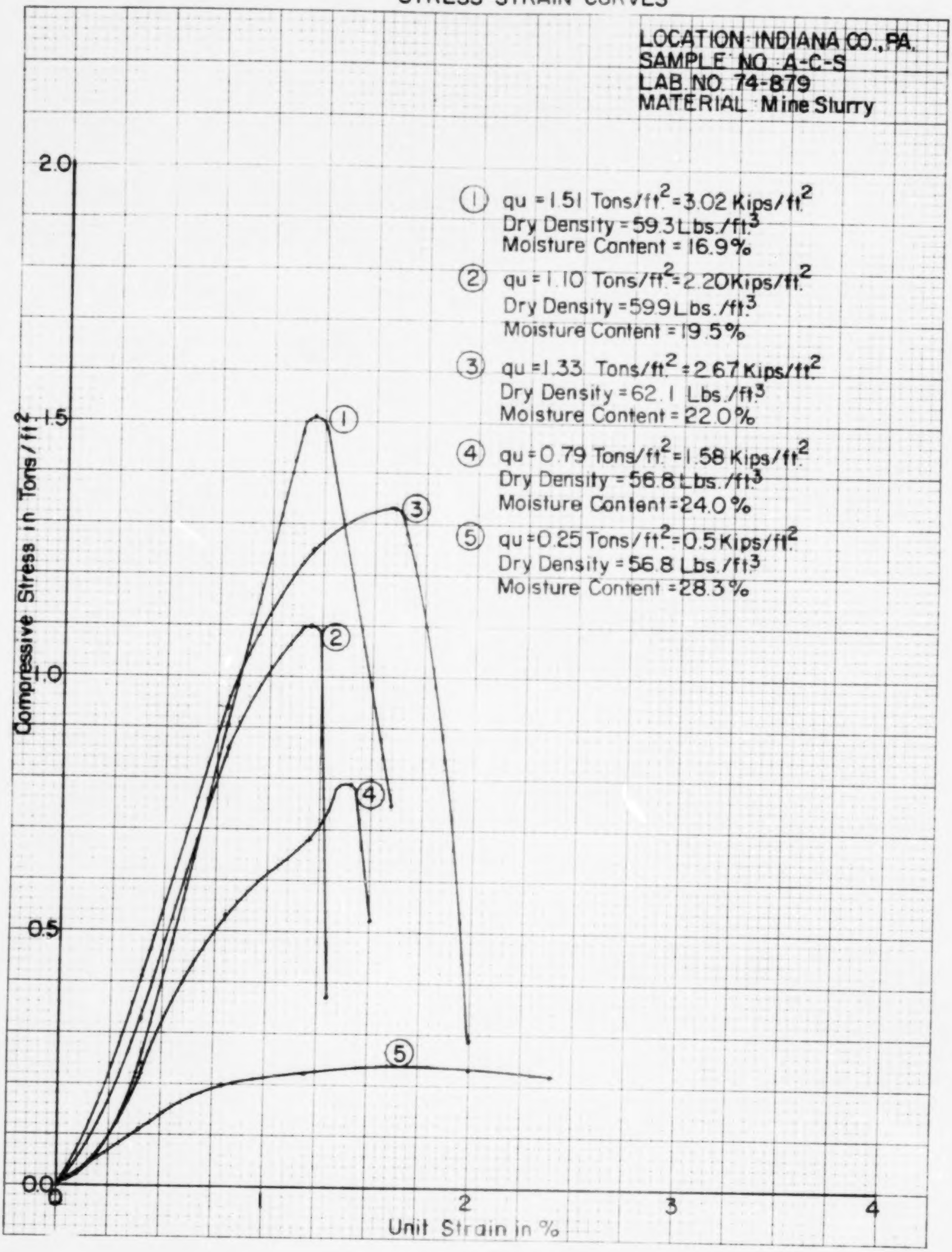
LOCATION: INDIANA CO., PA.
SAMPLE NO.: A-C-S
LAB. NO. 74-879
MATERIAL: Mine Slurry

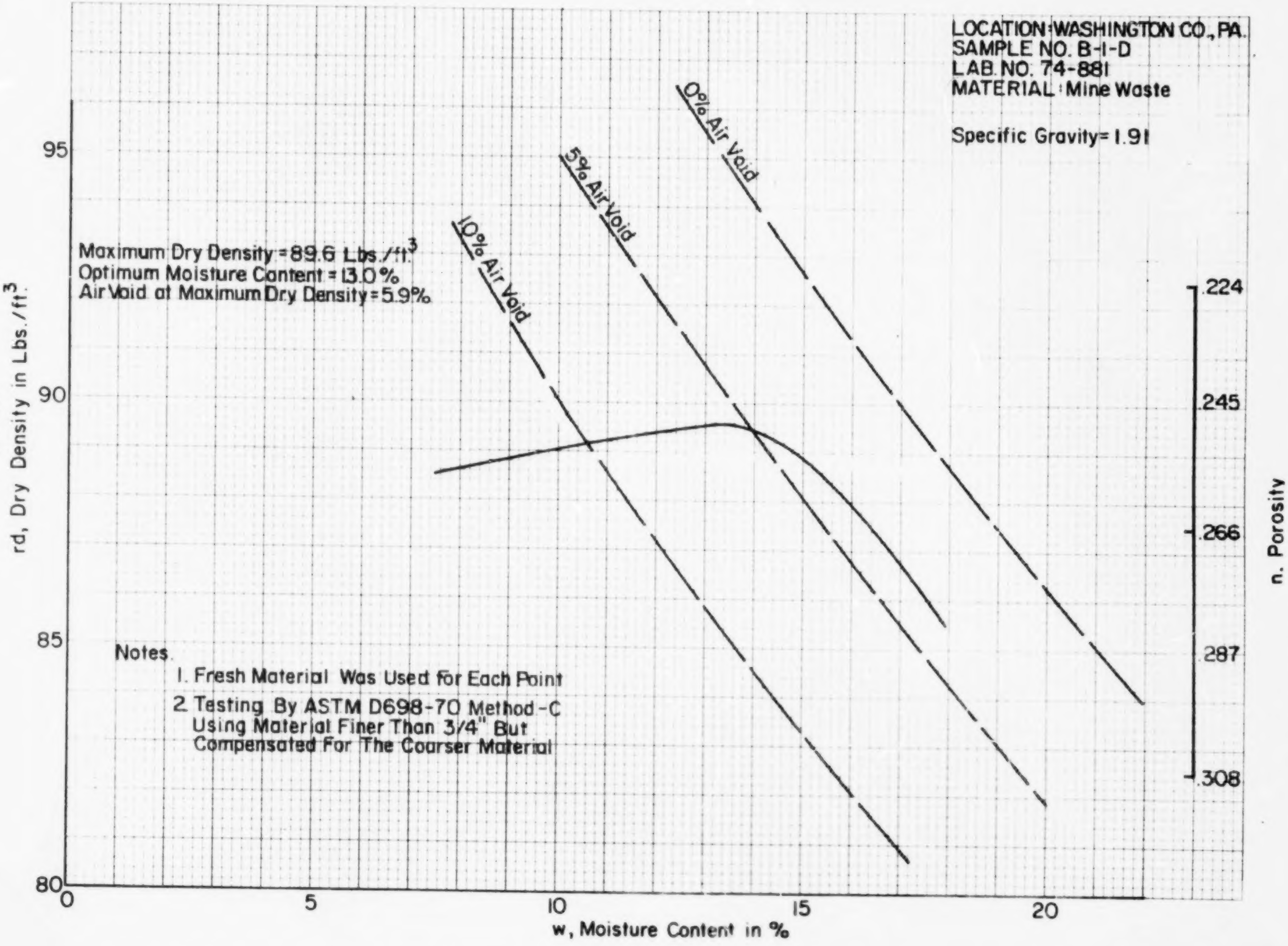
Specific Gravity = 1.35

Notes:
1. Fresh Material Was Used For Each Point
2. Tested By ASTM D698-70 Method-A Using Material Finer Than Sieve No. 4 (4.75 mm)

Maximum Dry Density = 60.0 Lbs./ft.^{3}
Optimum Moisture Content = 21.3 %
Air Void at Maximum Dry Density = 8.3%

UNCONFINED COMPRESSION TESTS
STRESS-STRAIN CURVES





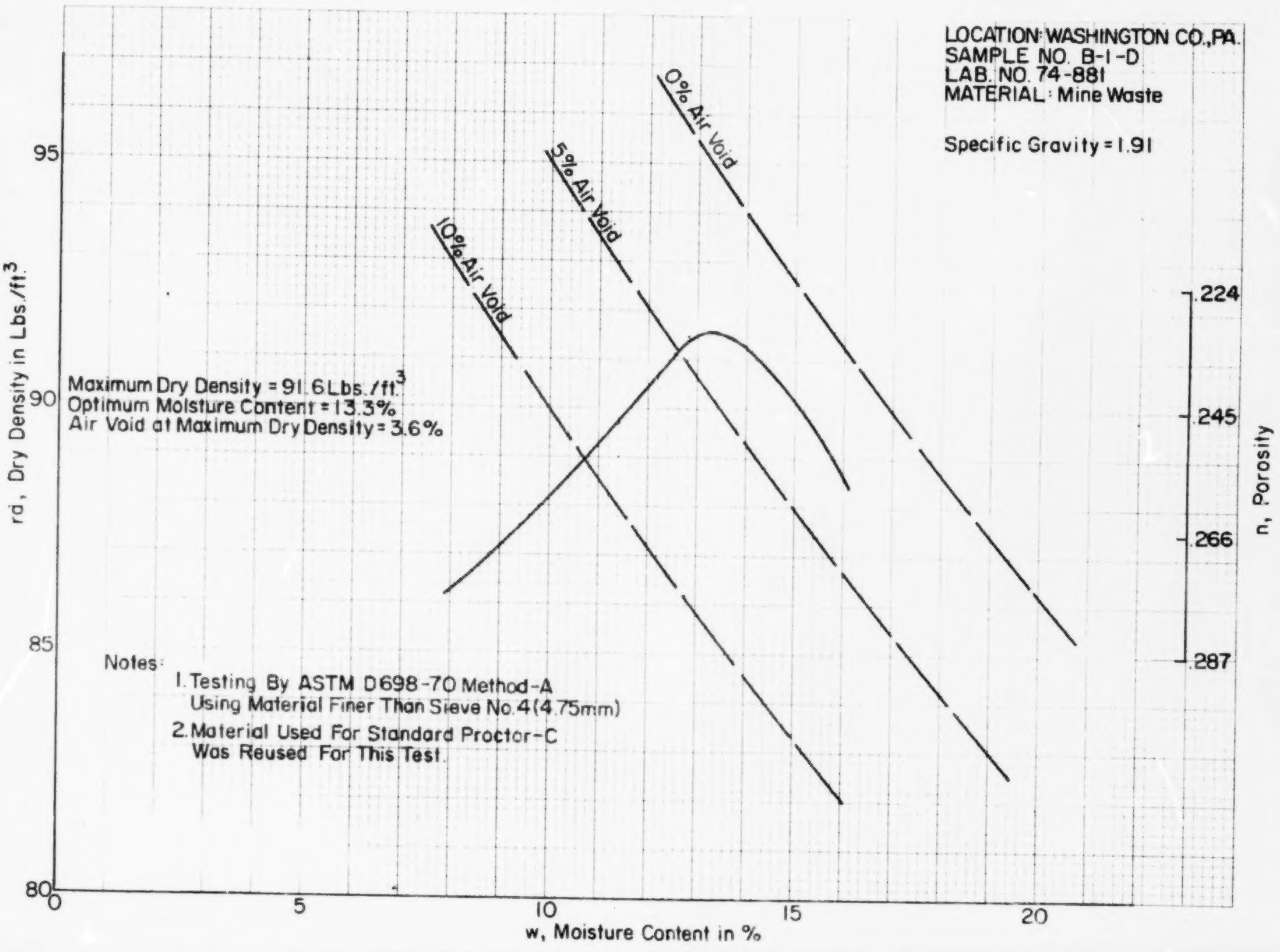
LOCATION: WASHINGTON CO., PA.
SAMPLE NO. B-1-D
LAB. NO. 74-881
MATERIAL: Mine Waste

Specific Gravity = 1.91

Maximum Dry Density = 89.6 Lbs./ft.^{3}
Optimum Moisture Content = 13.0 %
Air Void at Maximum Dry Density = 5.9%

Notes.

1. Fresh Material Was Used For Each Point
2. Testing By ASTM D698-70 Method-C Using Material Finer Than 3/4" But Compensated For The Coarser Material

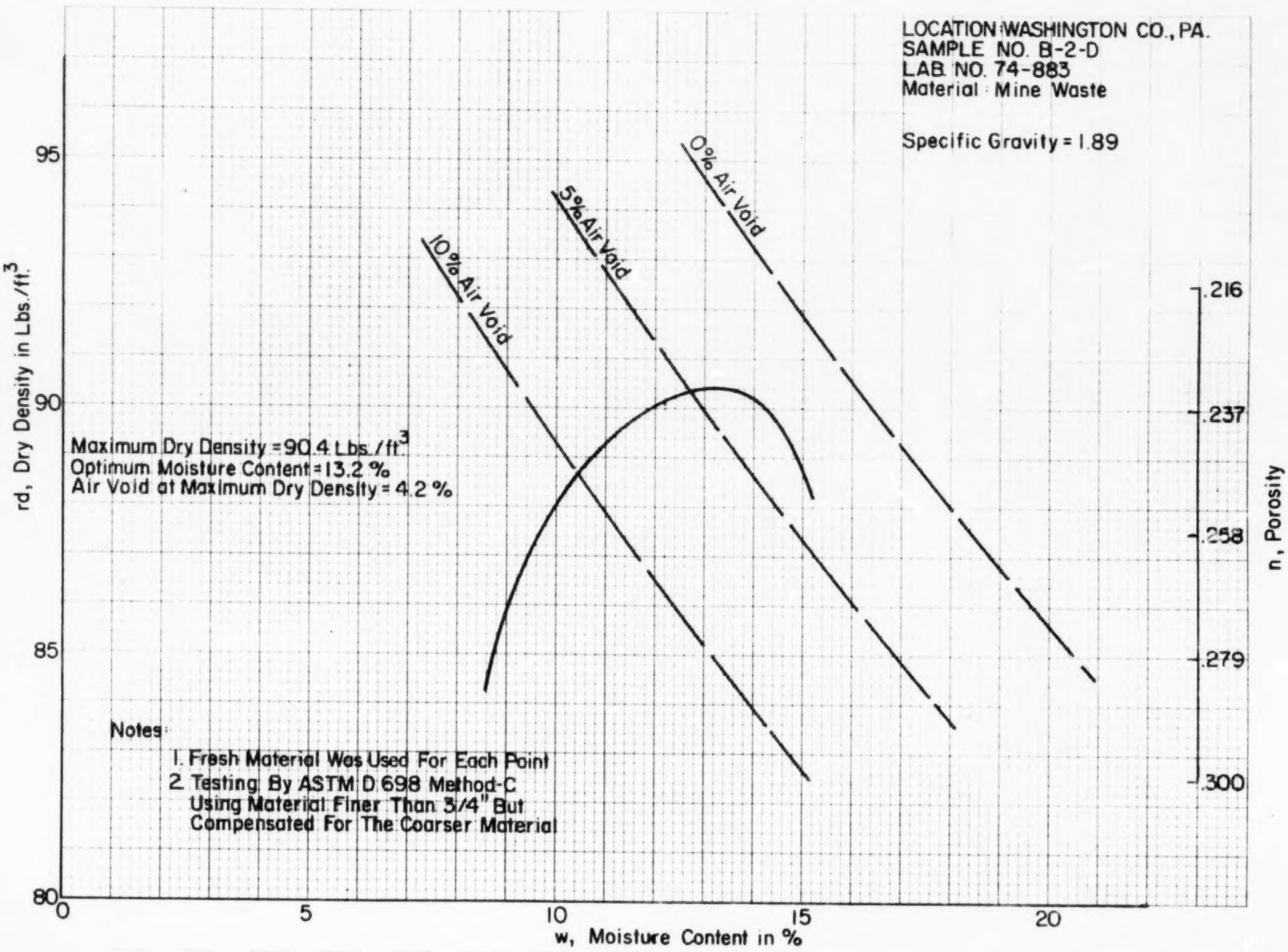

LOCATION: WASHINGTON CO., PA.
SAMPLE NO. B-1-D
LAB. NO. 74-881
MATERIAL: Mine Waste

Specific Gravity = 1.91

Maximum Dry Density = 91.6 Lbs./ft.^{3}
Optimum Moisture Content = 13.3%
Air Void at Maximum Dry Density = 3.6%

Notes:

1. Testing By ASTM D698-70 Method-A Using Material Finer Than Sieve No. 4 (4.75mm)
2. Material Used For Standard Proctor-C Was Reused For This Test.



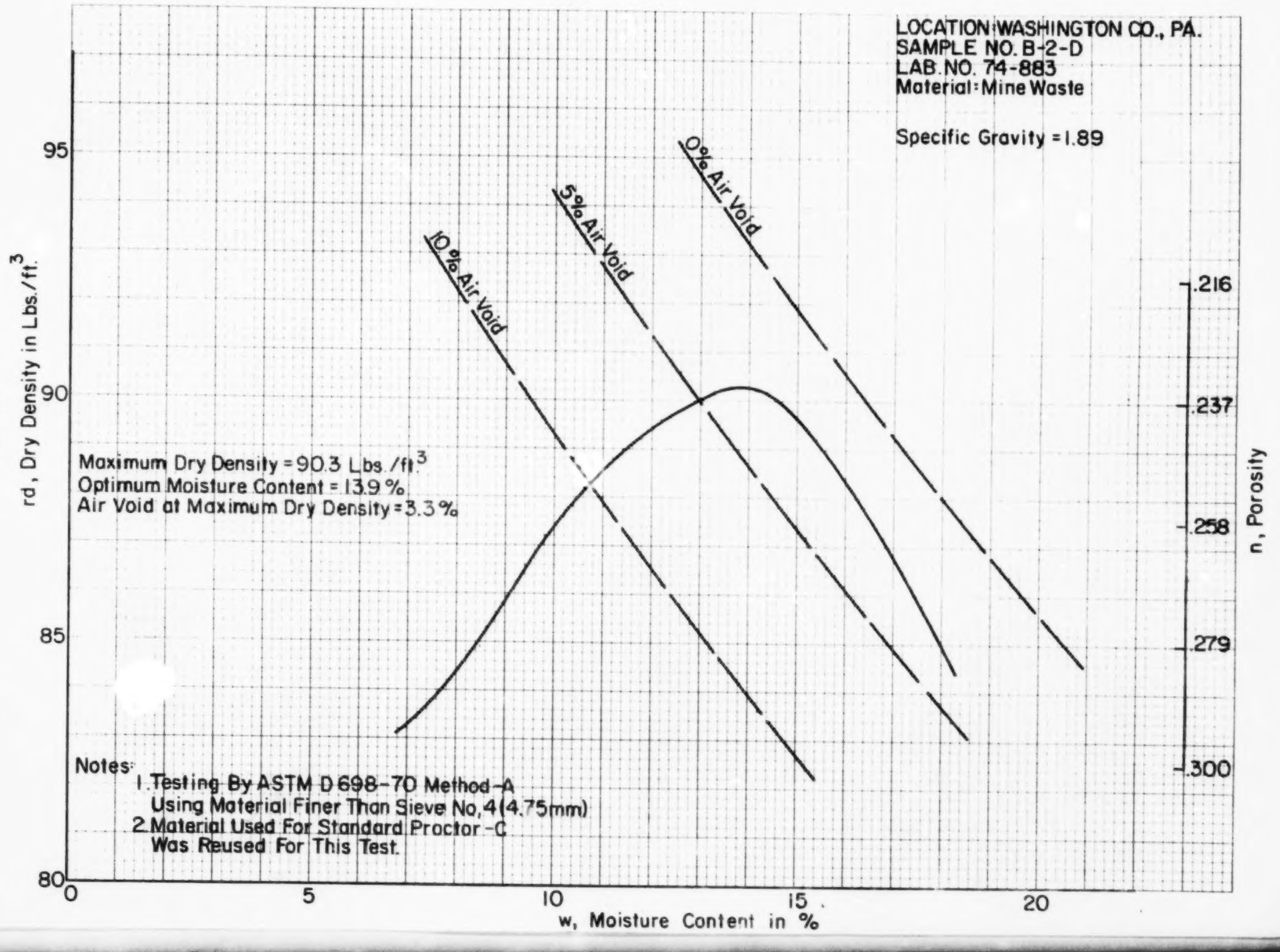
LOCATION:WASHINGTON CO., PA.
SAMPLE NO. B-2-D
LAB. NO. 74-883
Material : Mine Waste

Specific Gravity = 1.89

Maximum Dry Density = 90.4 Lbs./ft.^{3}
Optimum Moisture Content = 13.2 %
Air Void at Maximum Dry Density = 4.2 %

Notes:

1. Fresh Material Was Used For Each Point
2. Testing By ASTM D 698 Method-C Using Material Finer Than 3/4" But Compensated For The Coarser Material

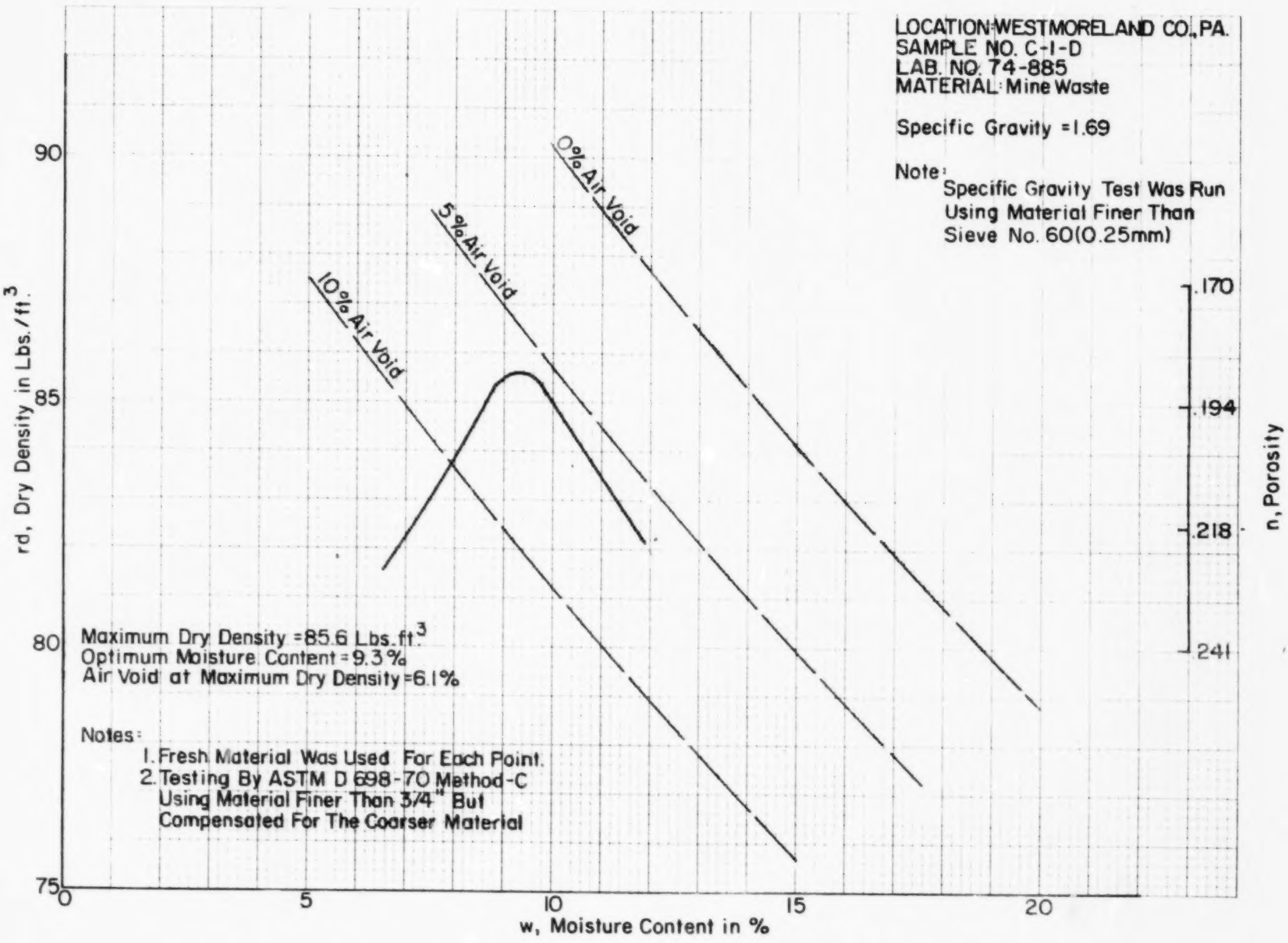


LOCATION: WASHINGTON CO., PA.
SAMPLE NO. B-2-D
LAB. NO. 74-883
Material: Mine Waste

Specific Gravity = 1.89

Maximum Dry Density = 90.3 Lbs./ft.^{3}
Optimum Moisture Content = 13.9 %
Air Void at Maximum Dry Density = 3.3 %

Notes:
1. Testing By ASTM D 698-70 Method-A Using Material Finer Than Sieve No. 4 (4.75mm)
2. Material Used For Standard Proctor -C Was Reused For This Test.



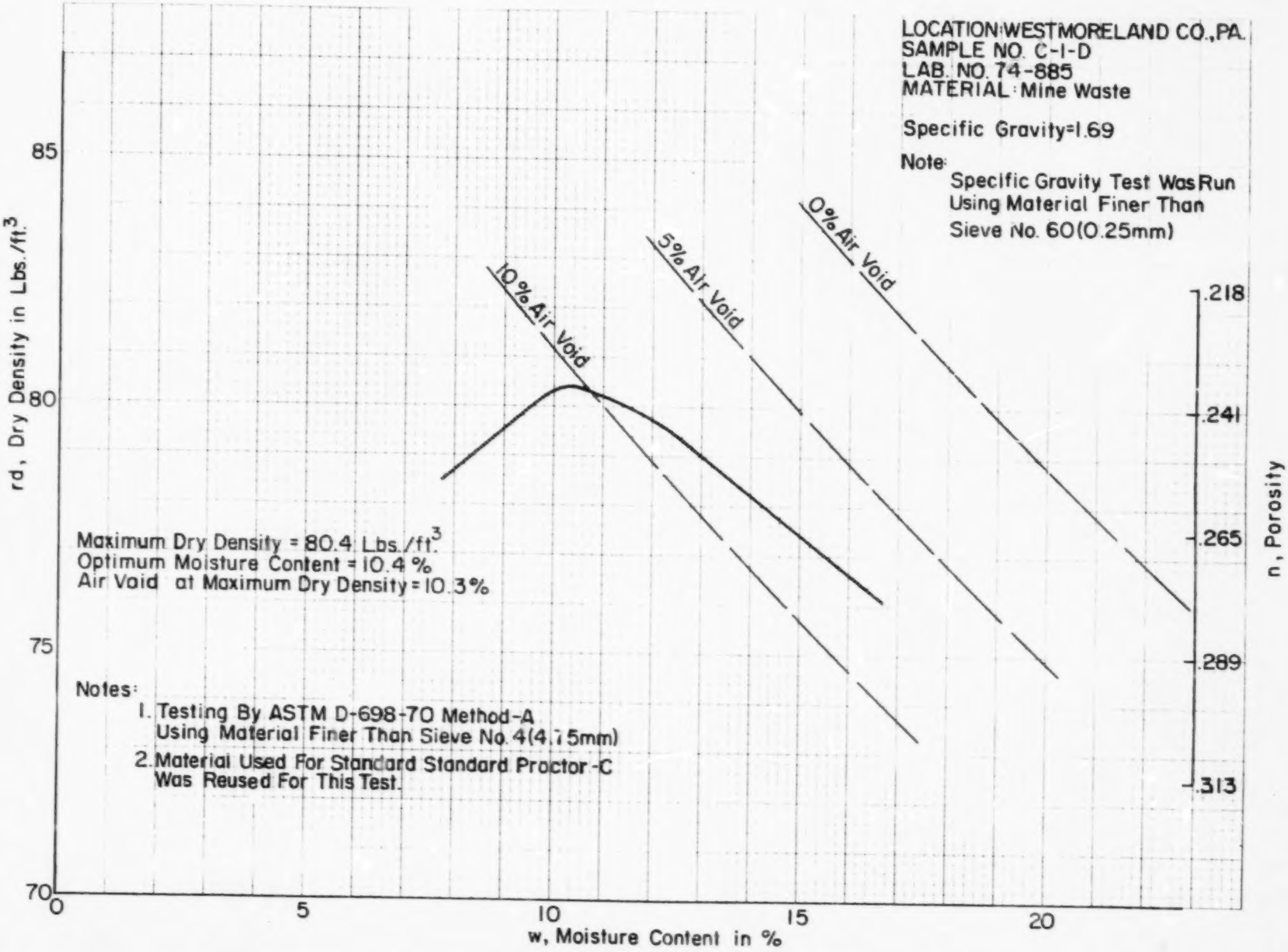
LOCATION: WESTMORELAND CO., PA.
SAMPLE NO. C-I-D
LAB. NO. 74-885
MATERIAL: Mine Waste

Specific Gravity = 1.69

Note:
Specific Gravity Test Was Run Using Material Finer Than Sieve No. 60 (0.25mm)

Maximum Dry Density = 85.6 Lbs. ft.^{3}
Optimum Moisture Content = 9.3%
Air Void at Maximum Dry Density = 6.1%

Notes:
1. Fresh Material Was Used For Each Point.
2. Testing By ASTM D 698-70 Method-C Using Material Finer Than 3/4" But Compensated For The Coarser Material



LOCATION: WESTMORELAND CO., PA.
SAMPLE NO. C-1-D
LAB. NO. 74-885
MATERIAL: Mine Waste

Specific Gravity=1.69

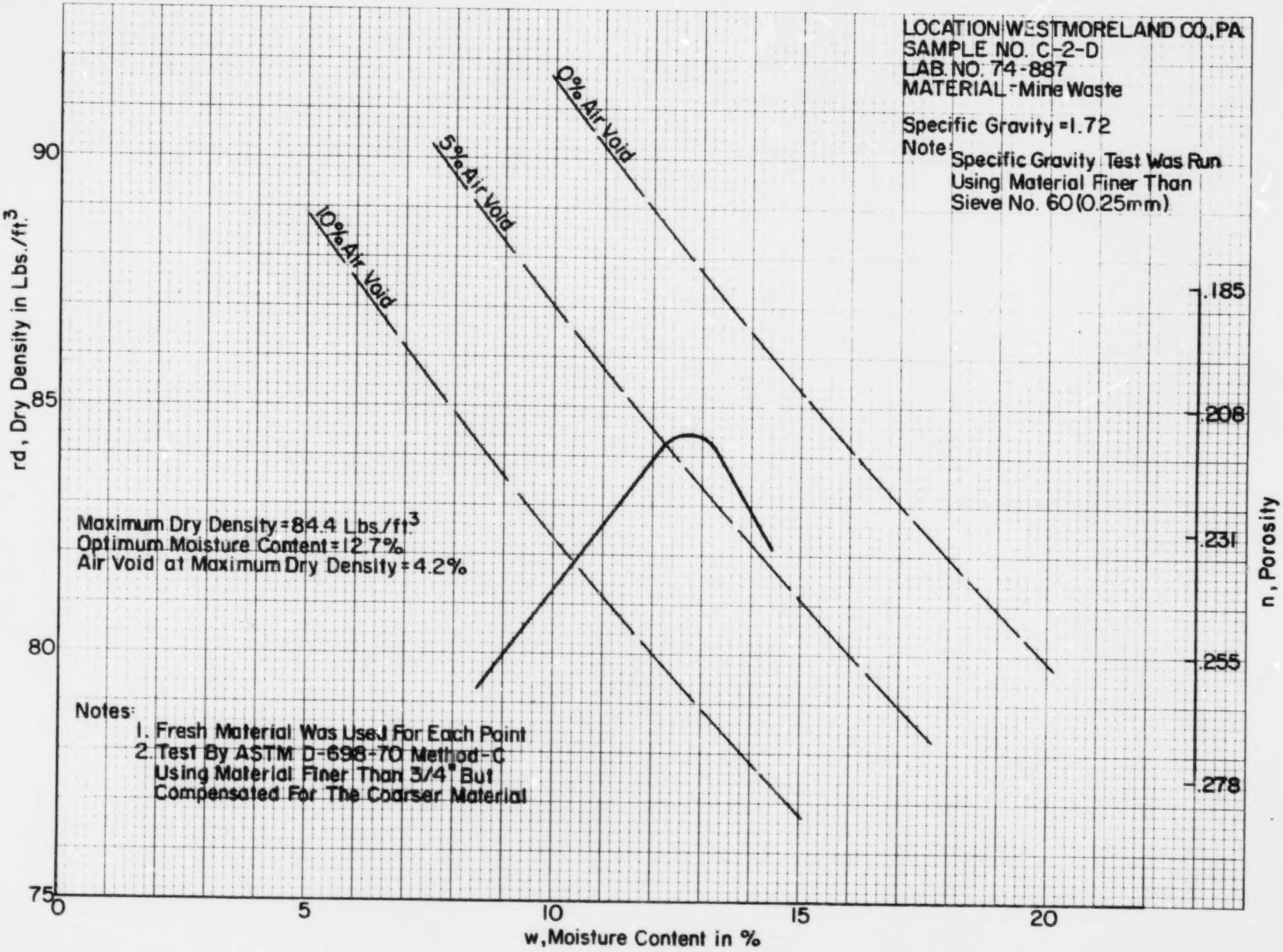
Note:
Specific Gravity Test Was Run Using Material Finer Than Sieve No. 60(0.25mm)

Maximum Dry Density = 80.4 Lbs./ft.^{3}
Optimum Moisture Content = 10.4 %
Air Void at Maximum Dry Density = 10.3%

Notes:

1. Testing By ASTM D-698-70 Method-A Using Material Finer Than Sieve No. 4(4.75mm)
2. Material Used For Standard Standard Proctor-C Was Reused For This Test.

rd, Dry Density in Lbs./ft.^{3}
85
80
75
70
0
5
10
15
20
w, Moisture Content in %
10% Air Void
5% Air Void
0% Air Void
n, Porosity
.218
.241
.265
.289
.313

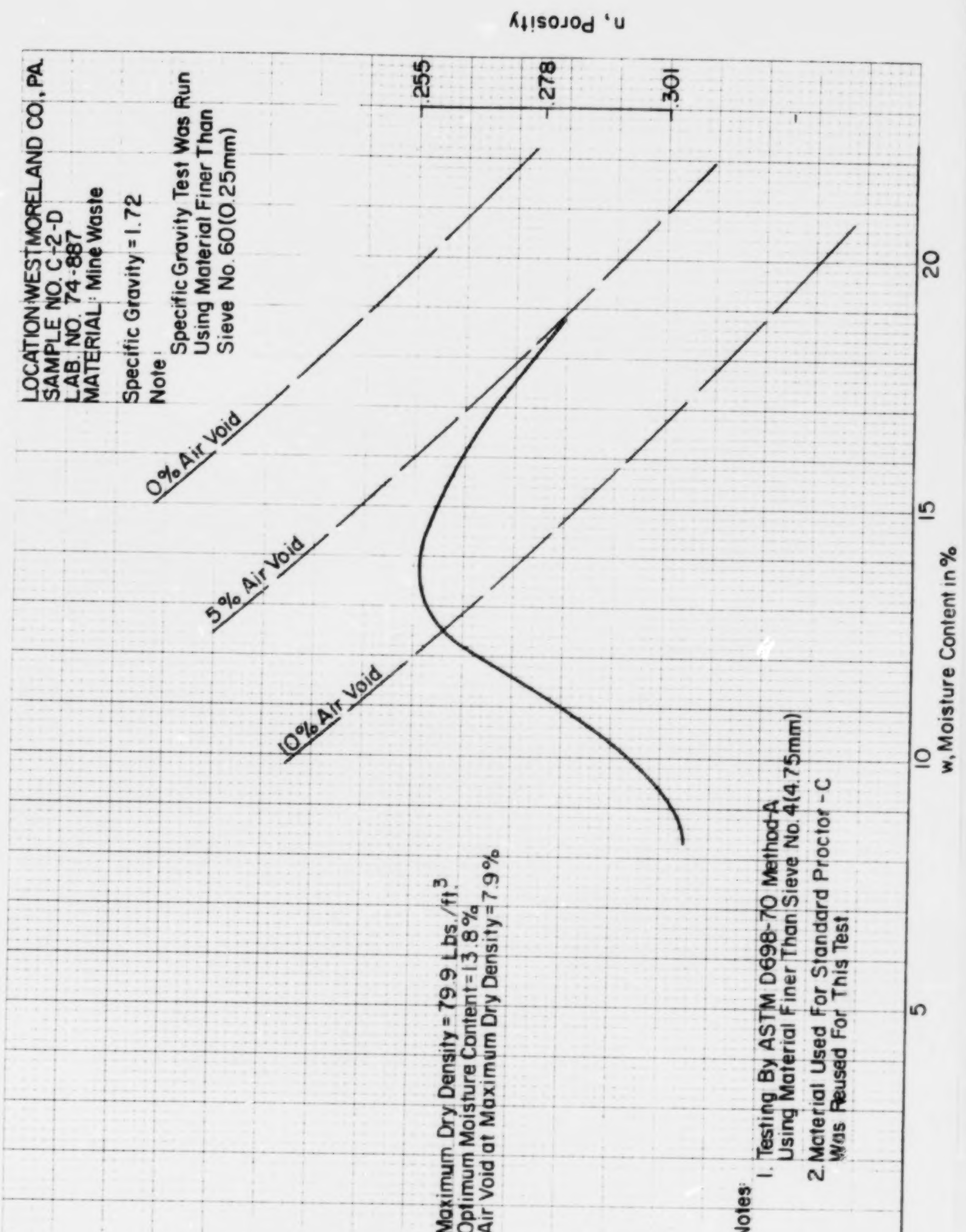


LOCATION WESTMORELAND CO., PA.
SAMPLE NO. C-2-D
LAB. NO. 74-887
MATERIAL - Mine Waste

Specific Gravity = 1.72
Note: Specific Gravity Test Was Run Using Material Finer Than Sieve No. 60 (0.25mm)

Maximum Dry Density = 84.4 Lbs./ft.^{3}
Optimum Moisture Content = 12.7%
Air Void at Maximum Dry Density = 4.2%

Notes:
1. Fresh Material Was Used For Each Point
2. Test By ASTM D-698-70 Method-C Using Material Finer Than 3/4" But Compensated For The Coarser Material



LOCATION: WESTMORELAND CO., PA.
SAMPLE NO. C-2-D
LAB. NO. 74-887
MATERIAL: Mine Waste

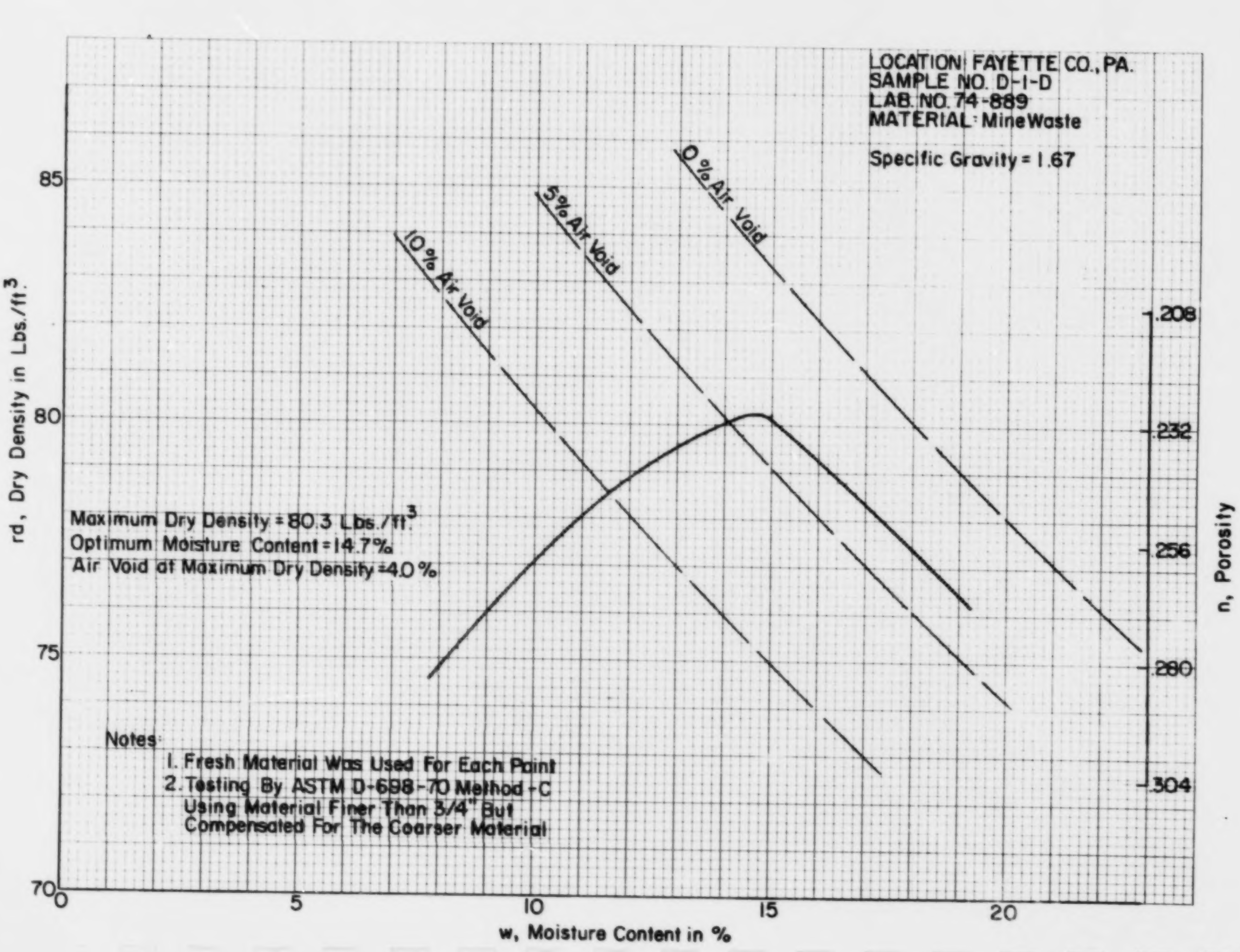
Specific Gravity = 1.72

Note:
Specific Gravity Test Was Run Using Material Finer Than Sieve No. 60(0.25mm)

Maximum Dry Density = 79.9 Lbs./ft.^{3}
Optimum Moisture Content = 13.8%
Air Void at Maximum Dry Density = 7.9%

Notes:
1. Testing By ASTM D698-70 Method-A Using Material Finer Than Sieve No. 4(4.75mm)
2. Material Used For Standard Proctor - C Was Reused For This Test.

n, Porosity
.255
.278
.301
0% Air Void
5% Air Void
10% Air Void
85
80
75
70
γd, Dry Density in Lbs./ft.^{3}
0
5
10
15
20
w, Moisture Content in %

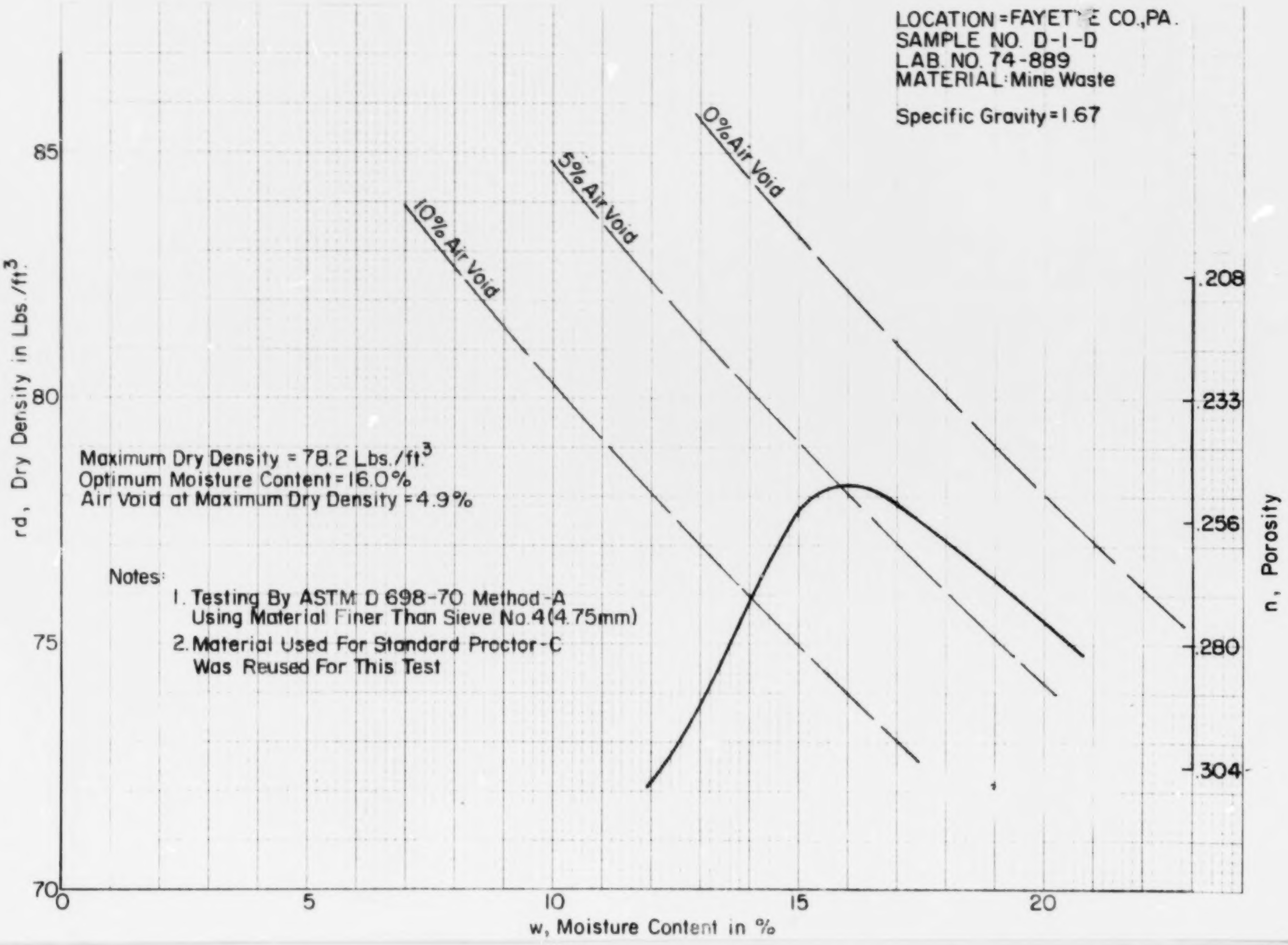


LOCATION: FAYETTE CO., PA.
SAMPLE NO. D-1-D
LAB. NO. 74-889
MATERIAL: Mine Waste

Specific Gravity = 1.67

Maximum Dry Density = 80.3 Lbs./ft.^{3}
Optimum Moisture Content = 14.7%
Air Void at Maximum Dry Density = 4.0 %

Notes:
1. Fresh Material Was Used For Each Point
2. Testing By ASTM D-698-70 Method-C Using Material Finer Than 3/4" But Compensated For The Coarser Material



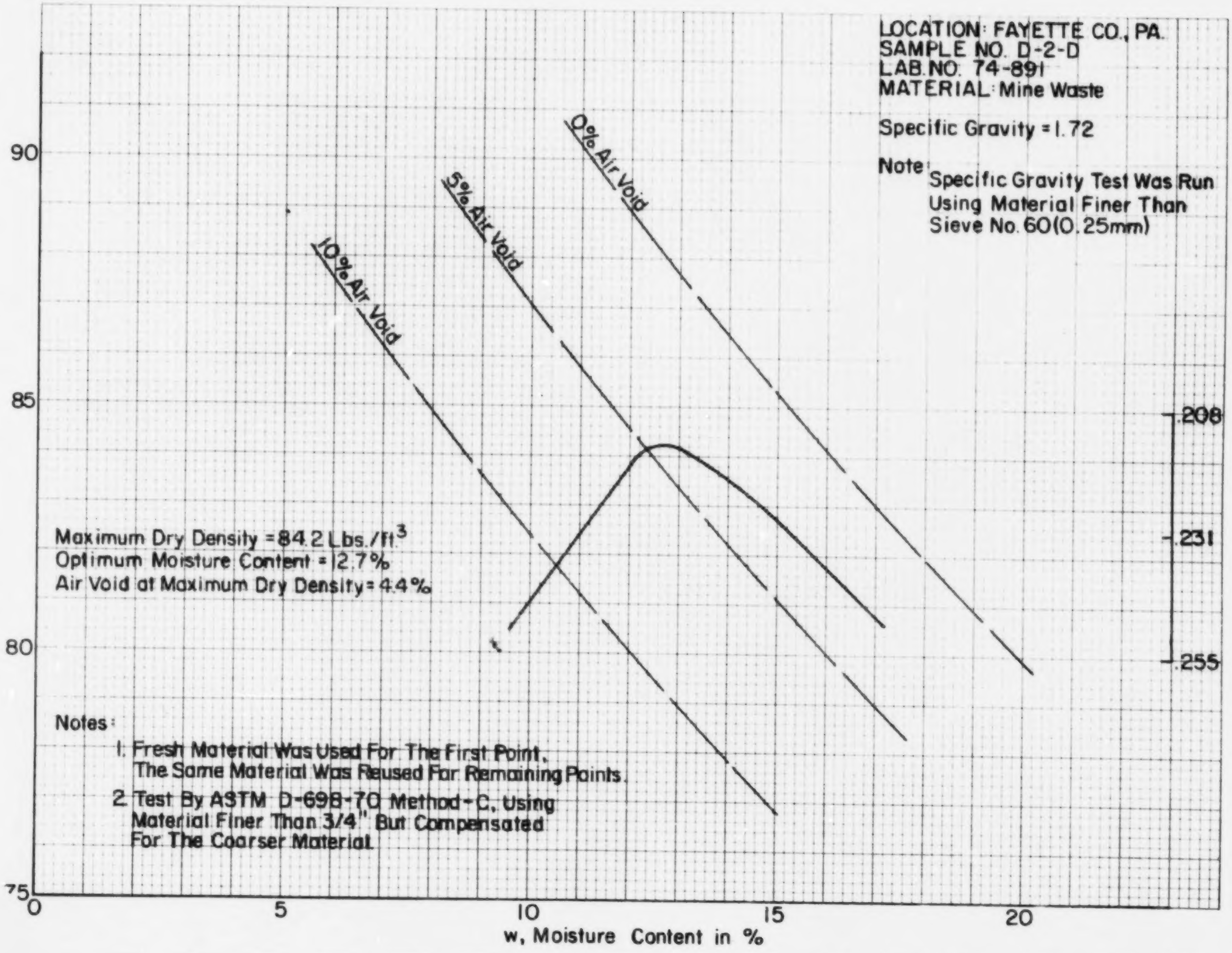
LOCATION = FAYETTE CO.,PA.
SAMPLE NO. D-1-D
LAB. NO. 74-889
MATERIAL: Mine Waste

Specific Gravity = 1.67

Maximum Dry Density = 78.2 Lbs./ft.^{3}
Optimum Moisture Content = 16.0%
Air Void at Maximum Dry Density = 4.9%

Notes:

1. Testing By ASTM D 698-70 Method-A Using Material Finer Than Sieve No.4(4.75mm)
2. Material Used For Standard Proctor-C Was Reused For This Test



LOCATION: FAYETTE CO., PA.
SAMPLE NO. D-2-D
LAB.NO. 74-891
MATERIAL: Mine Waste

Specific Gravity = 1.72

Note: Specific Gravity Test Was Run Using Material Finer Than Sieve No. 60(0.25mm)

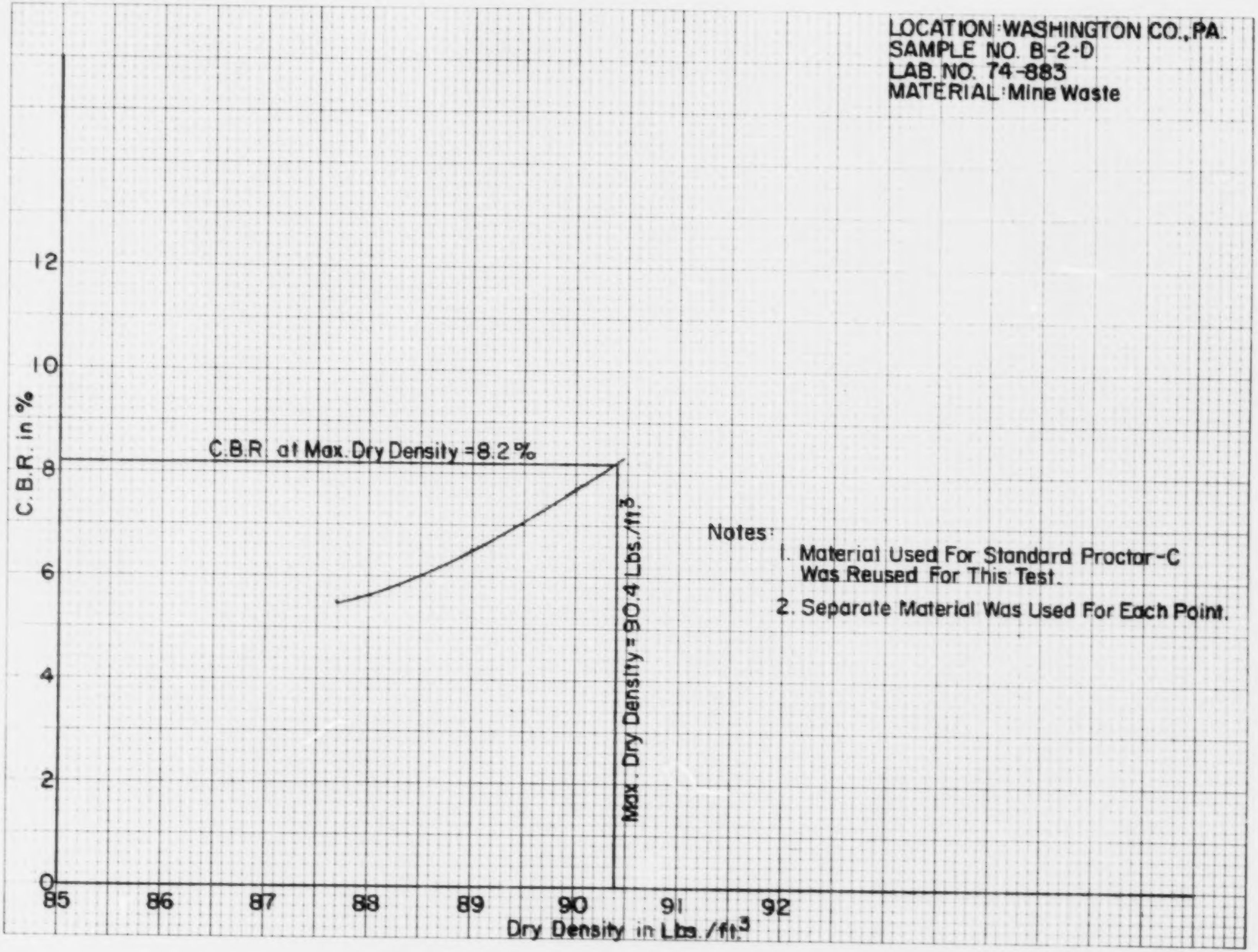
Maximum Dry Density = 84.2 Lbs./ft.^{3}
Optimum Moisture Content = 12.7%
Air Void at Maximum Dry Density = 4.4%

Notes:

1. Fresh Material Was Used For The First Point, The Same Material Was Reused For Remaining Points.
2. Test By ASTM D-698-70 Method - C, Using Material Finer Than 3/4" But Compensated For The Coarser Material.

EXHIBIT C

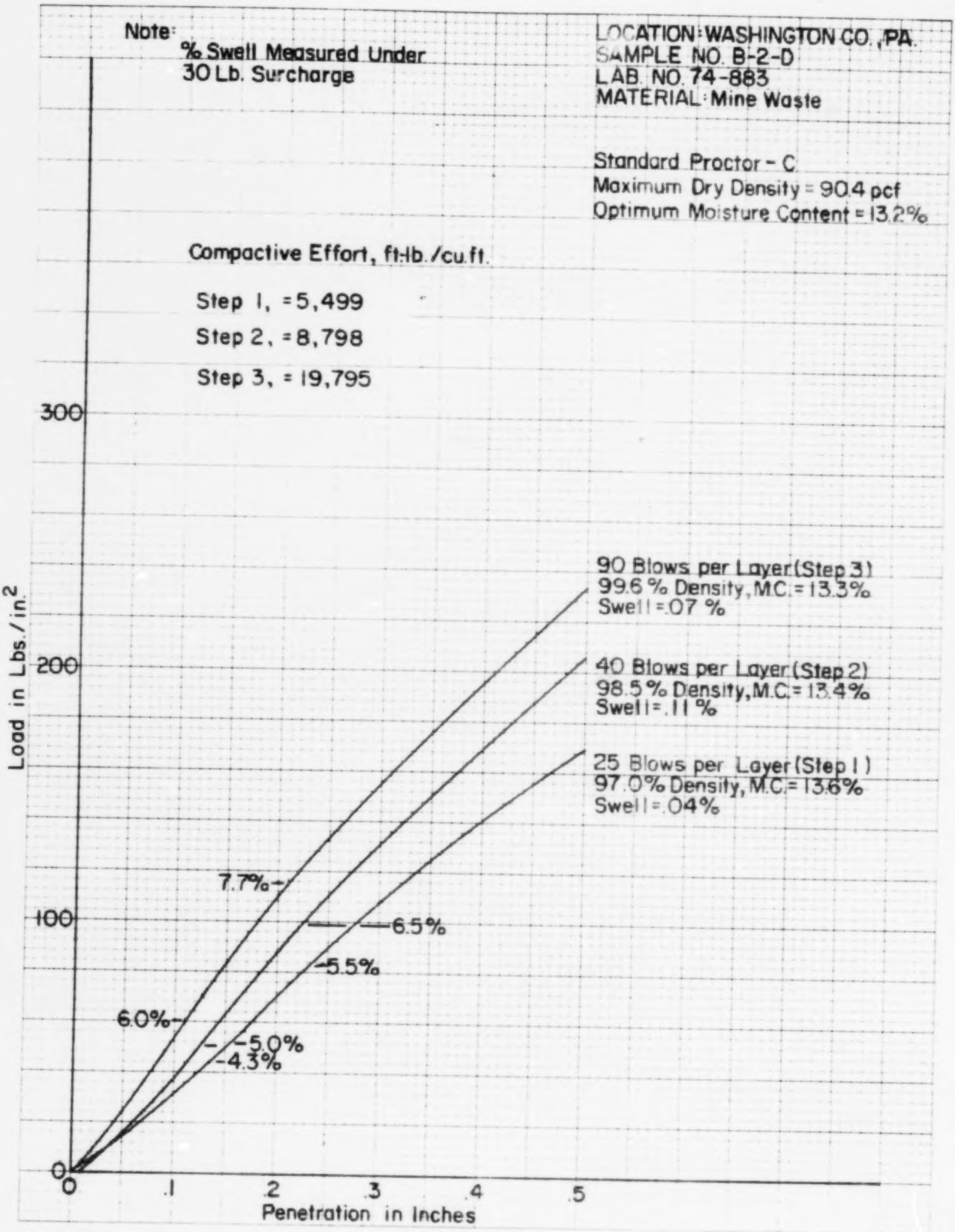
California Bearing Ratio

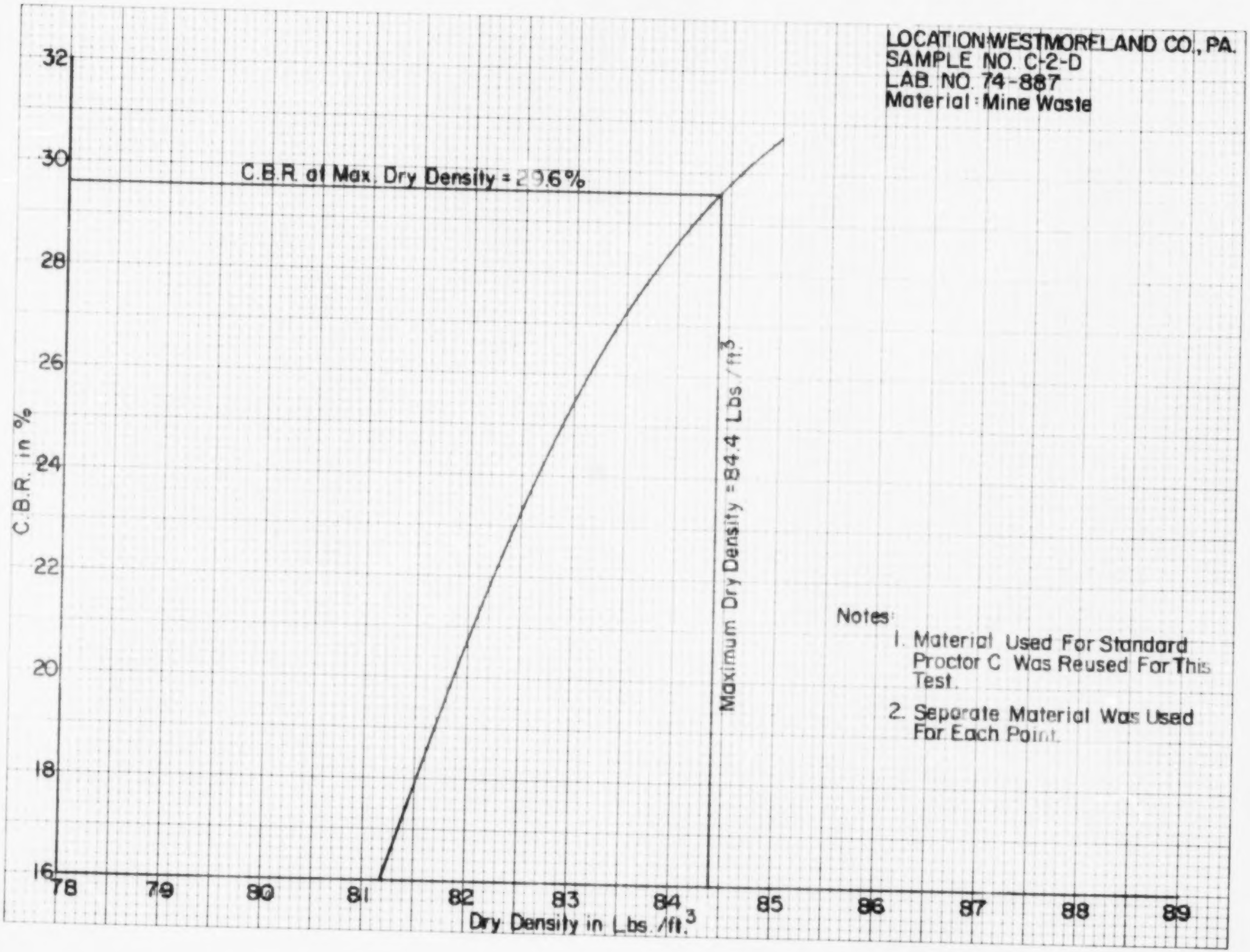


LOCATION: WASHINGTON CO., PA.
SAMPLE NO. B-2-D
LAB. NO. 74-883
MATERIAL: Mine Waste

Notes:

1. Material Used For Standard Proctor-C Was Reused For This Test.
2. Separate Material Was Used For Each Point.

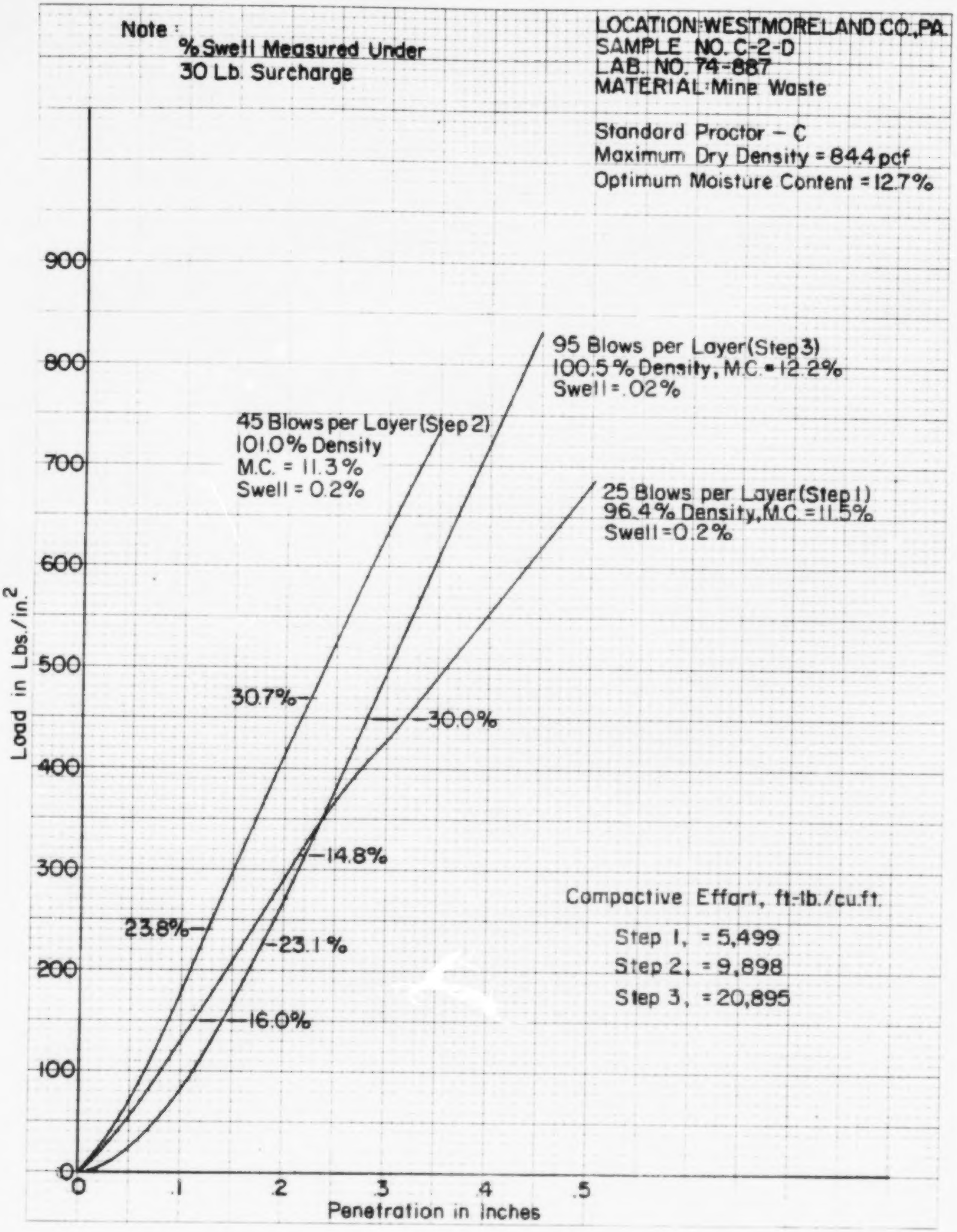

Note:
% Swell Measured Under
30 Lb. Surcharge
LOCATION: WASHINGTON CO., PA.
SAMPLE NO. B-2-D
LAB. NO. 74-883
MATERIAL: Mine Waste
Standard Proctor - C
Maximum Dry Density = 90.4 pcf
Optimum Moisture Content = 13.2%
Compactive Effort, ft-lb./cu.ft.
Step 1, = 5,499
Step 2, = 8,798
Step 3, = 19,795
90 Blows per Layer (Step 3)
99.6 % Density, M.C. = 13.3%
Swell = .07 %
40 Blows per Layer (Step 2)
98.5 % Density, M.C. = 13.4%
Swell = .11 %
25 Blows per Layer (Step 1)
97.0% Density, M.C. = 13.6%
Swell = .04%
7.7%
6.5%
5.5%
6.0%
5.0%
4.3%
Load in Lbs./in.²
300
200
100
0
0
.1
.2
.3
.4
.5
Penetration in Inches

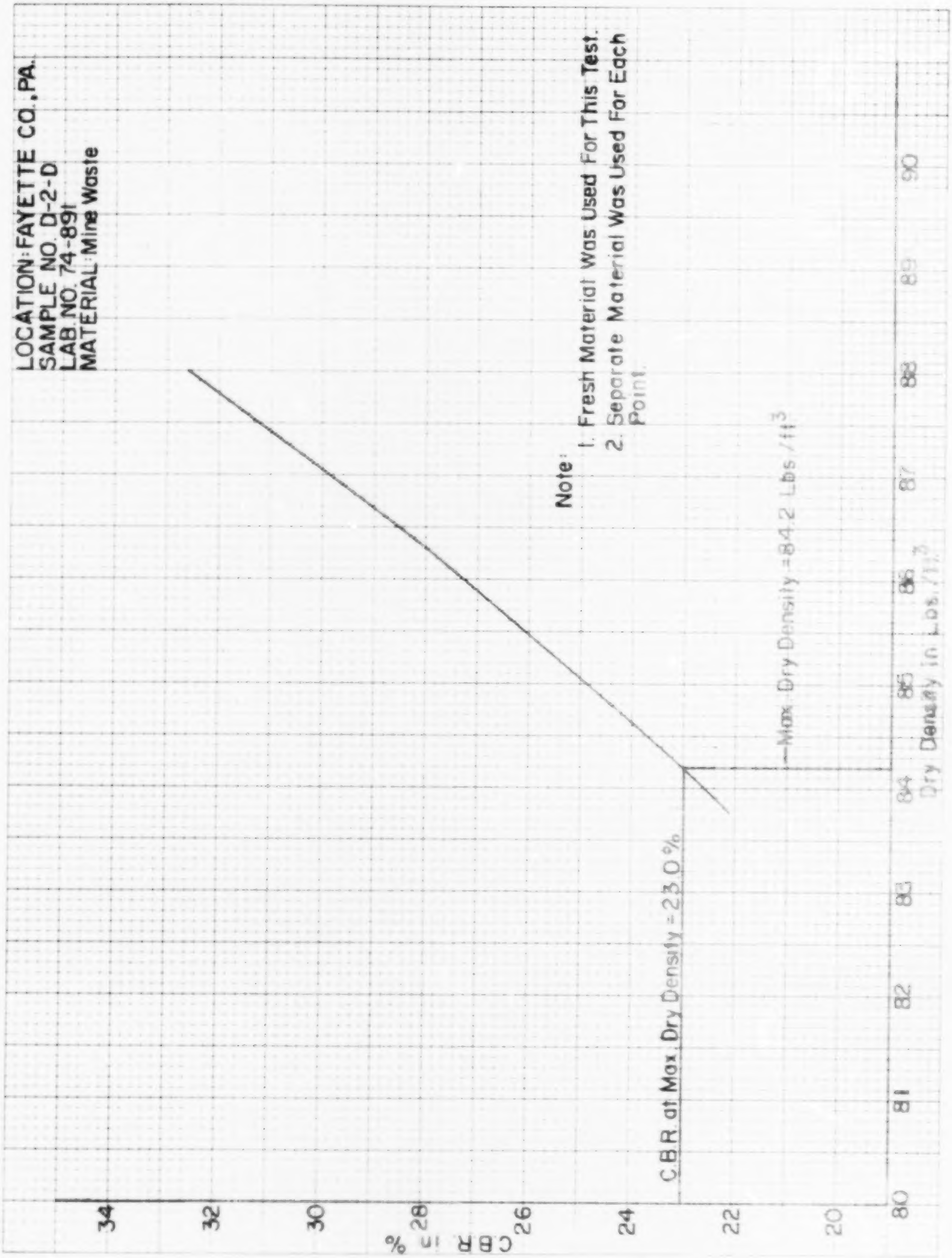


LOCATION:WESTMORELAND CO., PA.
SAMPLE NO. C-2-D
LAB. NO. 74-887
Material: Mine Waste

Notes:

1. Material Used For Standard Proctor C Was Reused For This Test.
2. Separate Material Was Used For Each Point.


Note :
% Swell Measured Under
30 Lb. Surcharge
LOCATION: WESTMORELAND CO., PA.
SAMPLE NO. C-2-D
LAB. NO. 74-887
MATERIAL: Mine Waste
Standard Proctor – C
Maximum Dry Density = 84.4 pcf
Optimum Moisture Content = 12.7%
95 Blows per Layer (Step 3)
100.5 % Density, M.C. = 12.2%
Swell = .02%
45 Blows per Layer (Step 2)
101.0% Density
M.C. = 11.3%
Swell = 0.2%
25 Blows per Layer (Step 1)
96.4% Density, M.C. = 11.5%
Swell = 0.2%
30.7%
30.0%
14.8%
23.8%
23.1%
16.0%
Compactive Effort, ft.-lb./cu.ft.
Step 1, = 5,499
Step 2, = 9,898
Step 3, = 20,895
Load in Lbs./in.²
900
800
700
600
500
400
300
200
100
0
Penetration in Inches
0
.1
.2
.3
.4
.5


LOCATION: FAYETTE CO., PA.
SAMPLE NO. D-2-D
LAB. NO. 74-891
MATERIAL: Mine Waste
Note:
1. Fresh Material Was Used For This Test.
2. Separate Material Was Used For Each Point.
C.B.R. at Max. Dry Density = 23.0 %
Max. Dry Density = 84.2 Lbs./ft³
C.B.R. in %
34
32
30
28
26
24
22
20
Dry Density in Lbs./ft³
80
81
82
83
84
85
86
87
88
89
90

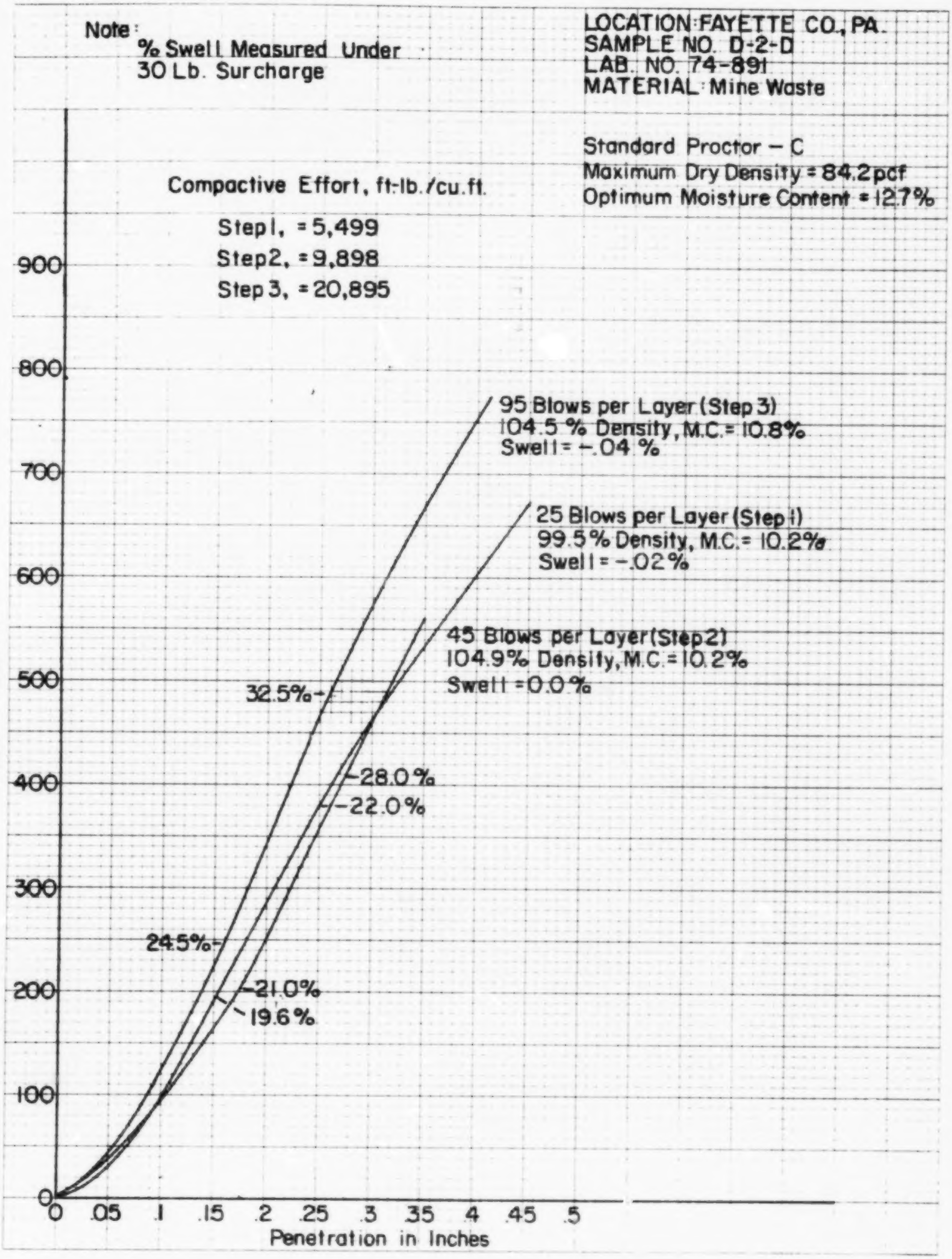

Note:
% Swell Measured Under
30 Lb. Surcharge
LOCATION: FAYETTE CO., PA.
SAMPLE NO. D-2-D
LAB. NO. 74-891
MATERIAL: Mine Waste
Standard Proctor – C
Maximum Dry Density = 84.2 pcf
Optimum Moisture Content = 12.7%
Compactive Effort, ft-lb./cu.ft.
Step 1, = 5,499
Step 2, = 9,898
Step 3, = 20,895
95 Blows per Layer (Step 3)
104.5 % Density, M.C. = 10.8%
Swell = –.04 %
25 Blows per Layer (Step 1)
99.5 % Density, M.C. = 10.2%
Swell = –.02%
45 Blows per Layer (Step 2)
104.9% Density, M.C. = 10.2%
Swell = 0.0%
32.5%
28.0%
22.0%
24.5%
21.0%
19.6%
Load in Lbs./in.^{2}
0
100
200
300
400
500
600
700
800
900
0
.05
.1
.15
.2
.25
.3
.35
.4
.45
.5
Penetration in Inches

EXHIBIT D

Consolidated Undrained Triaxial Tests

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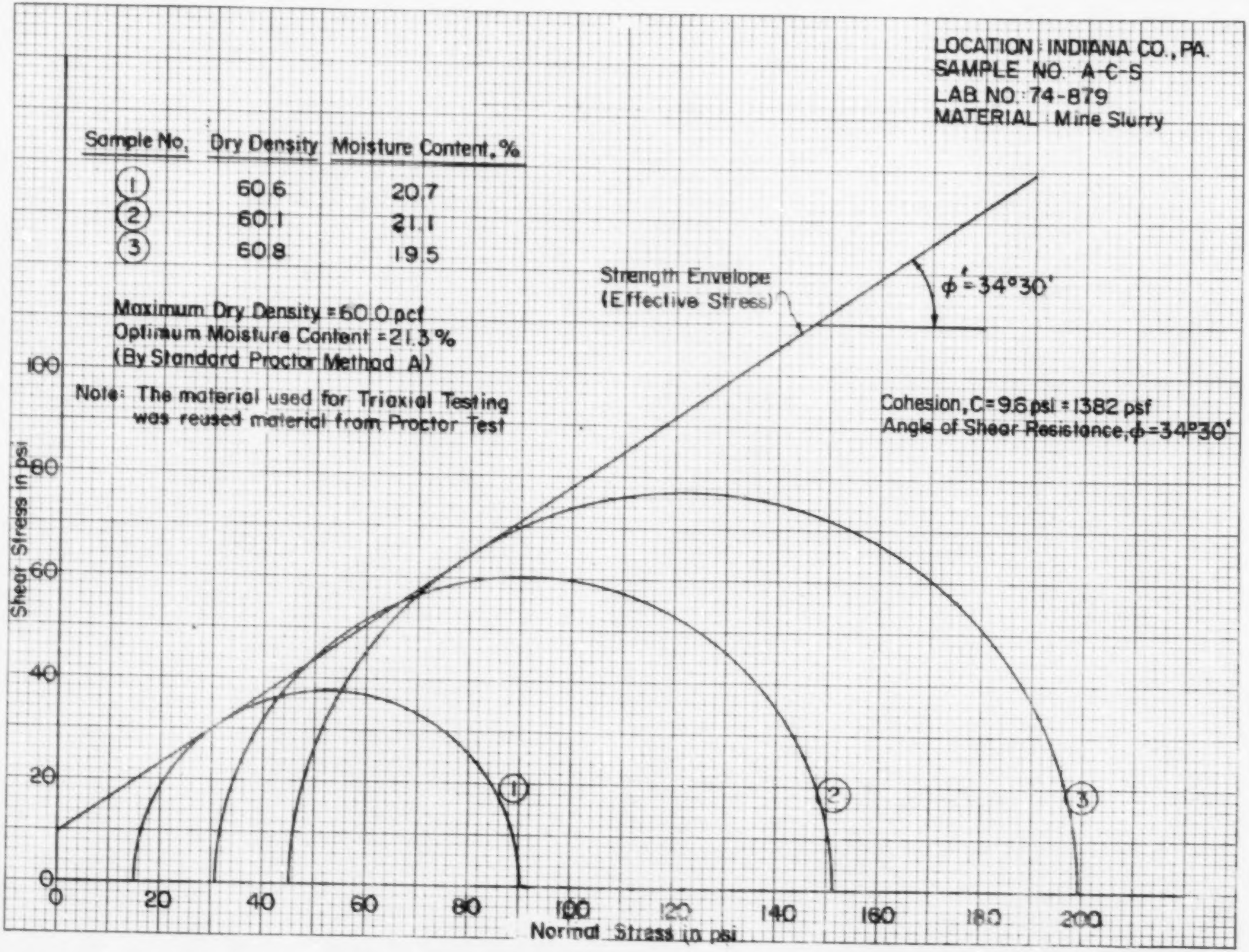


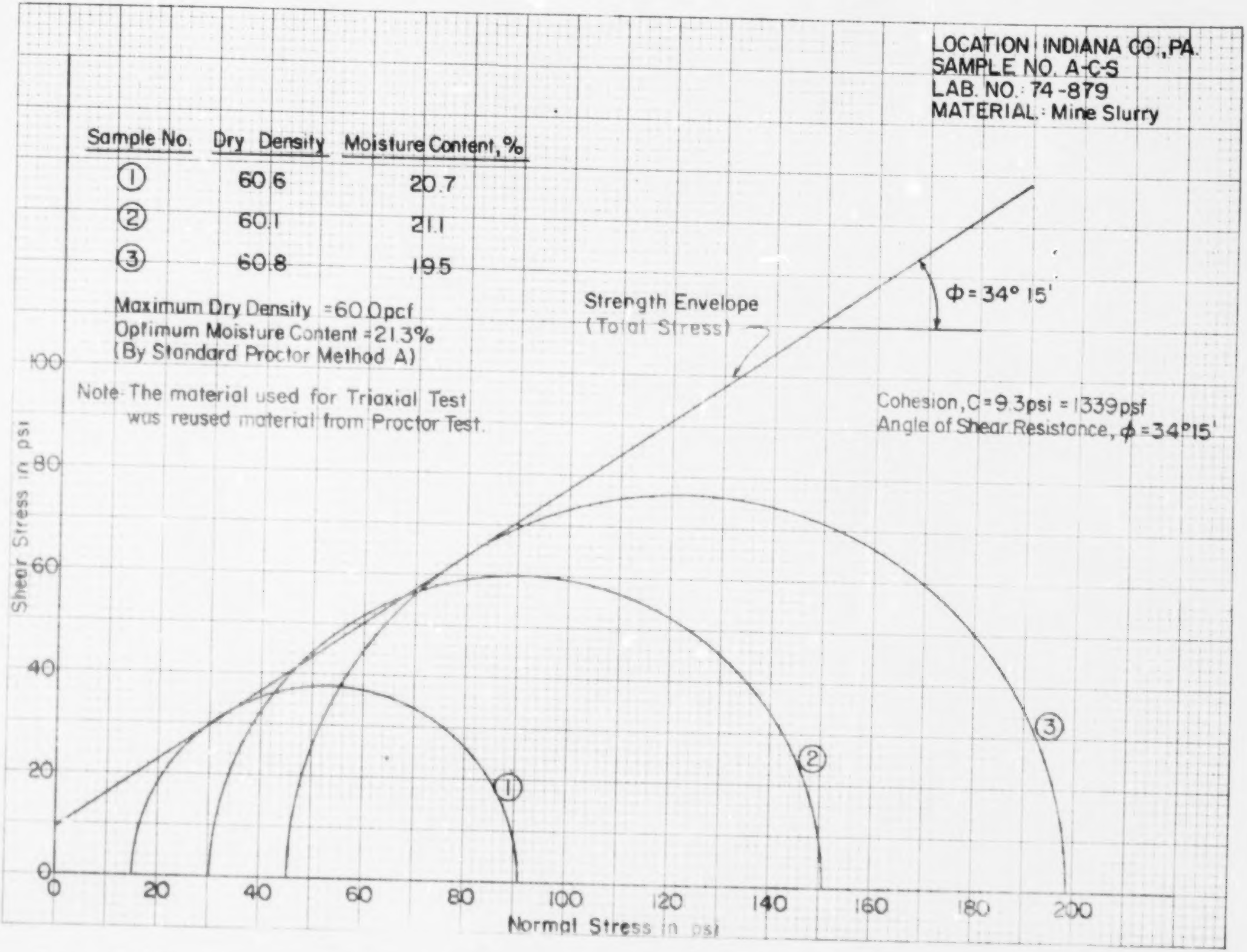
LOCATION: INDIANA CO., PA.
SAMPLE NO. A-C-S
LAB NO: 74-879
MATERIAL: Mine Slurry

Sample No.	Dry Density	Moisture Content, %
①	60.6	20.7
②	60.1	21.1
③	60.8	19.5

Maximum Dry Density = 60.0 pcf
Optimum Moisture Content = 21.3 %
(By Standard Proctor Method A)

Note: The material used for Triaxial Testing was reused material from Proctor Test

Cohesion, C = 9.6 psi = 1382 psf
Angle of Shear Resistance, $\phi = 34°30'$



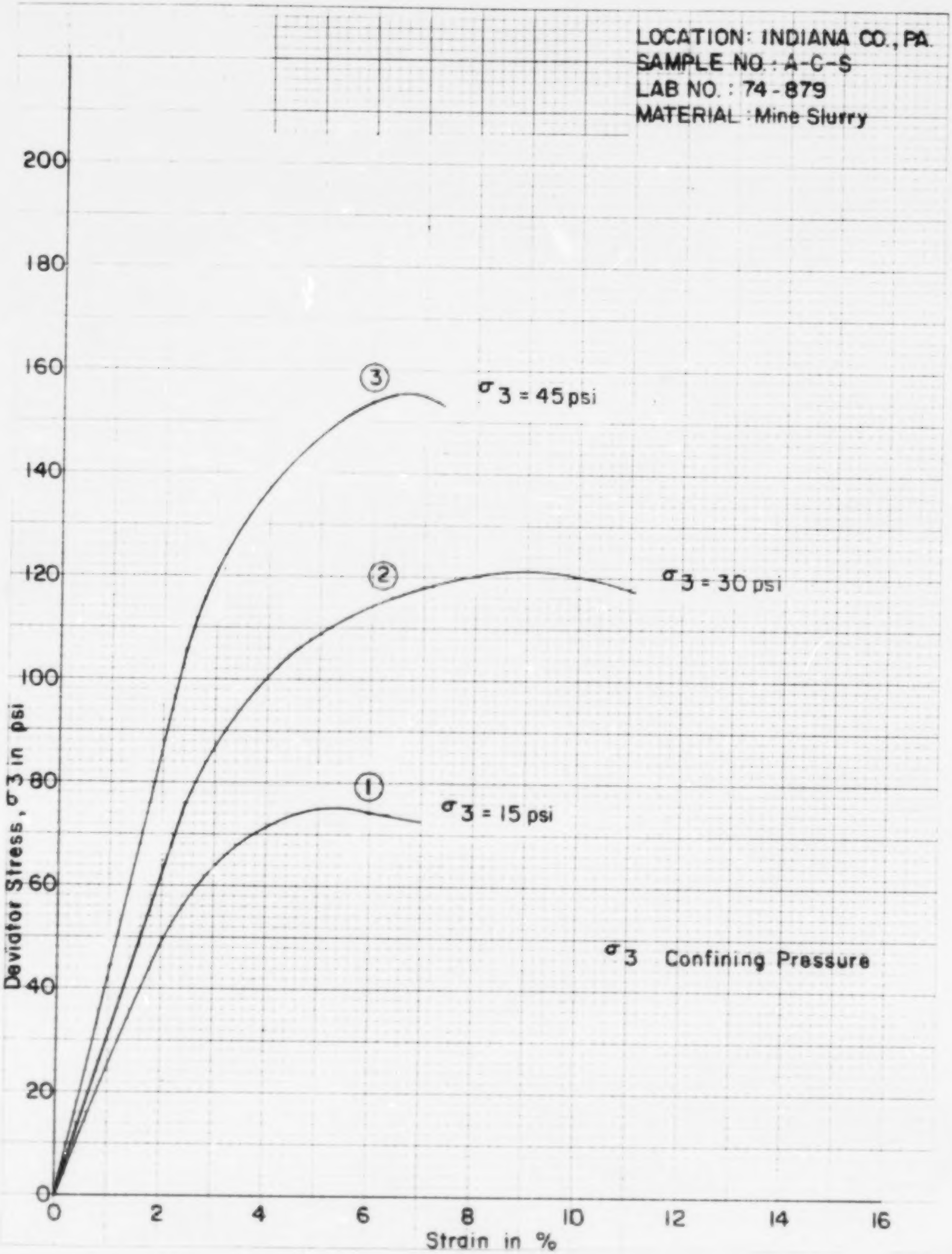
LOCATION: INDIANA CO., PA.
SAMPLE NO. A-C-S
LAB. NO.: 74-879
MATERIAL: Mine Slurry

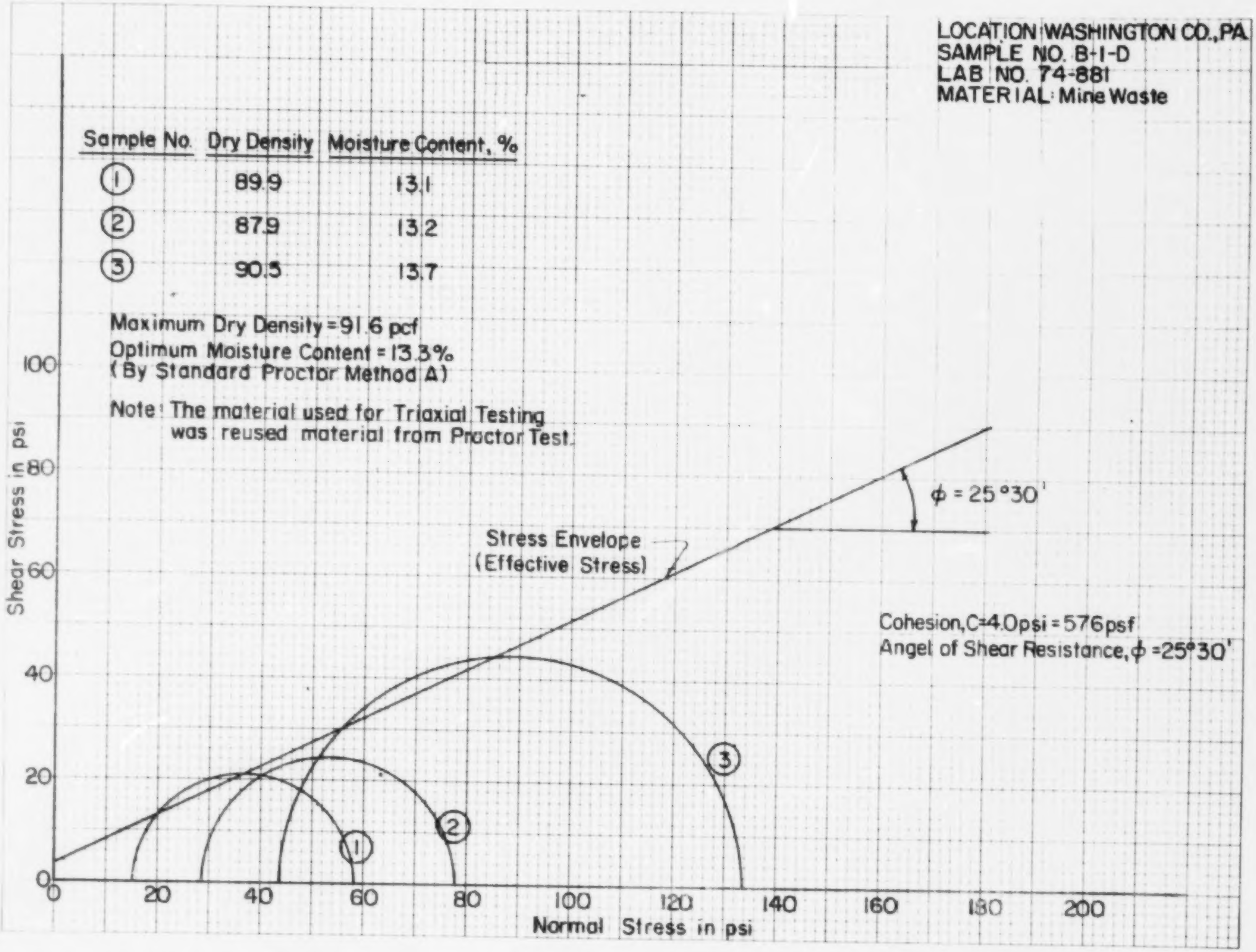
Sample No.	Dry Density	Moisture Content, %
①	60.6	20.7
②	60.1	21.1
③	60.8	19.5

Maximum Dry Density = 60.0 pcf
Optimum Moisture Content = 21.3%
(By Standard Proctor Method A)

Note: The material used for Triaxial Test was reused material from Proctor Test.

Cohesion, C = 9.3 psi = 1339 psf
Angle of Shear Resistance, ϕ = 34°15'


LOCATION: INDIANA CO., PA.
SAMPLE NO.: A-C-S
LAB NO.: 74-879
MATERIAL: Mine Slurry
③
σ3 = 45 psi
②
σ3 = 30 psi
①
σ3 = 15 psi
σ3 Confining Pressure
Deviator Stress, σ3 in psi
0
20
40
60
80
100
120
140
160
180
200
0
2
4
6
8
10
12
14
16
Strain in %



LOCATION: WASHINGTON CO., PA
SAMPLE NO. B-1-D
LAB NO. 74-881
MATERIAL: Mine Waste

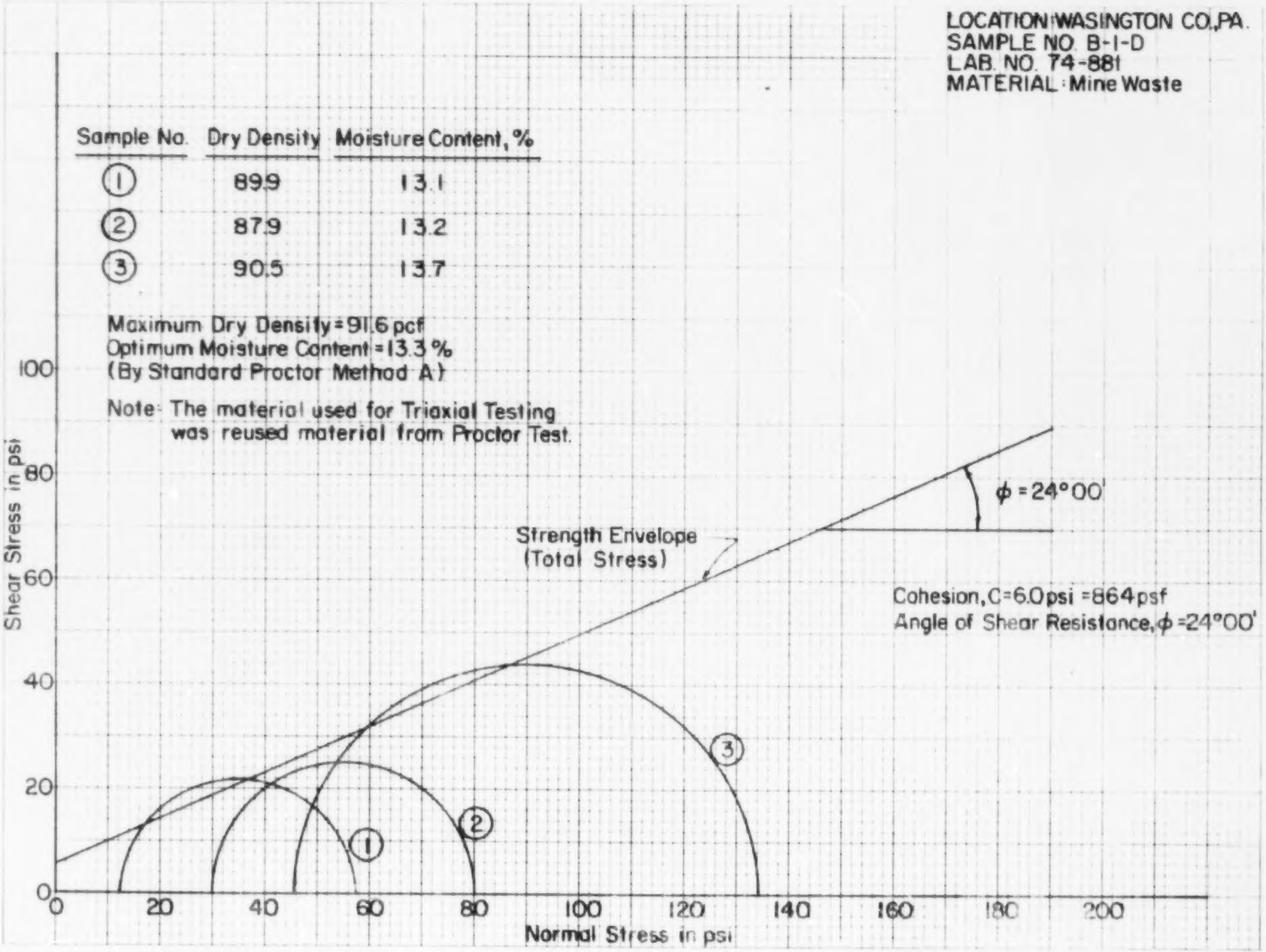
Sample No.	Dry Density	Moisture Content, %
①	89.9	13.1
②	87.9	13.2
③	90.5	13.7

Maximum Dry Density = 91.6 pcf
Optimum Moisture Content = 13.3%
(By Standard Proctor Method A)

Note: The material used for Triaxial Testing was reused material from Proctor Test.

Cohesion, C=4.0psi = 576psf
Angel of Shear Resistance, ϕ = 25°30'

Shear Stress in psi
0
20
40
60
80
100
Normal Stress in psi
0
20
40
60
80
100
120
140
160
180
200
①
②
③
Stress Envelope
(Effective Stress)
ϕ = 25°30'



LOCATION: WASINGTON CO, PA.
SAMPLE NO. B-1-D
LAB. NO. 74-881
MATERIAL: Mine Waste

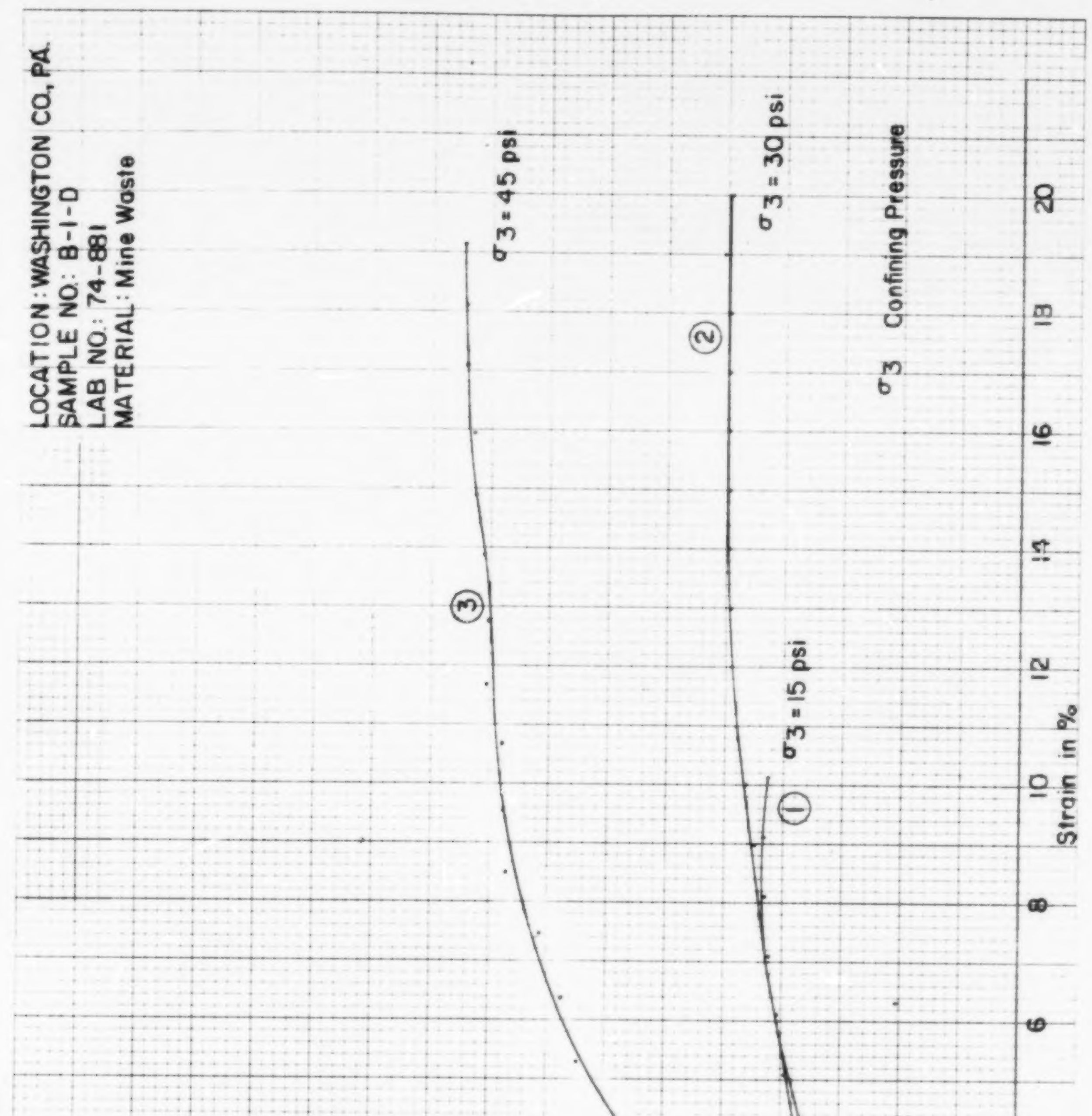
Sample No.	Dry Density	Moisture Content, %
①	89.9	13.1
②	87.9	13.2
③	90.5	13.7

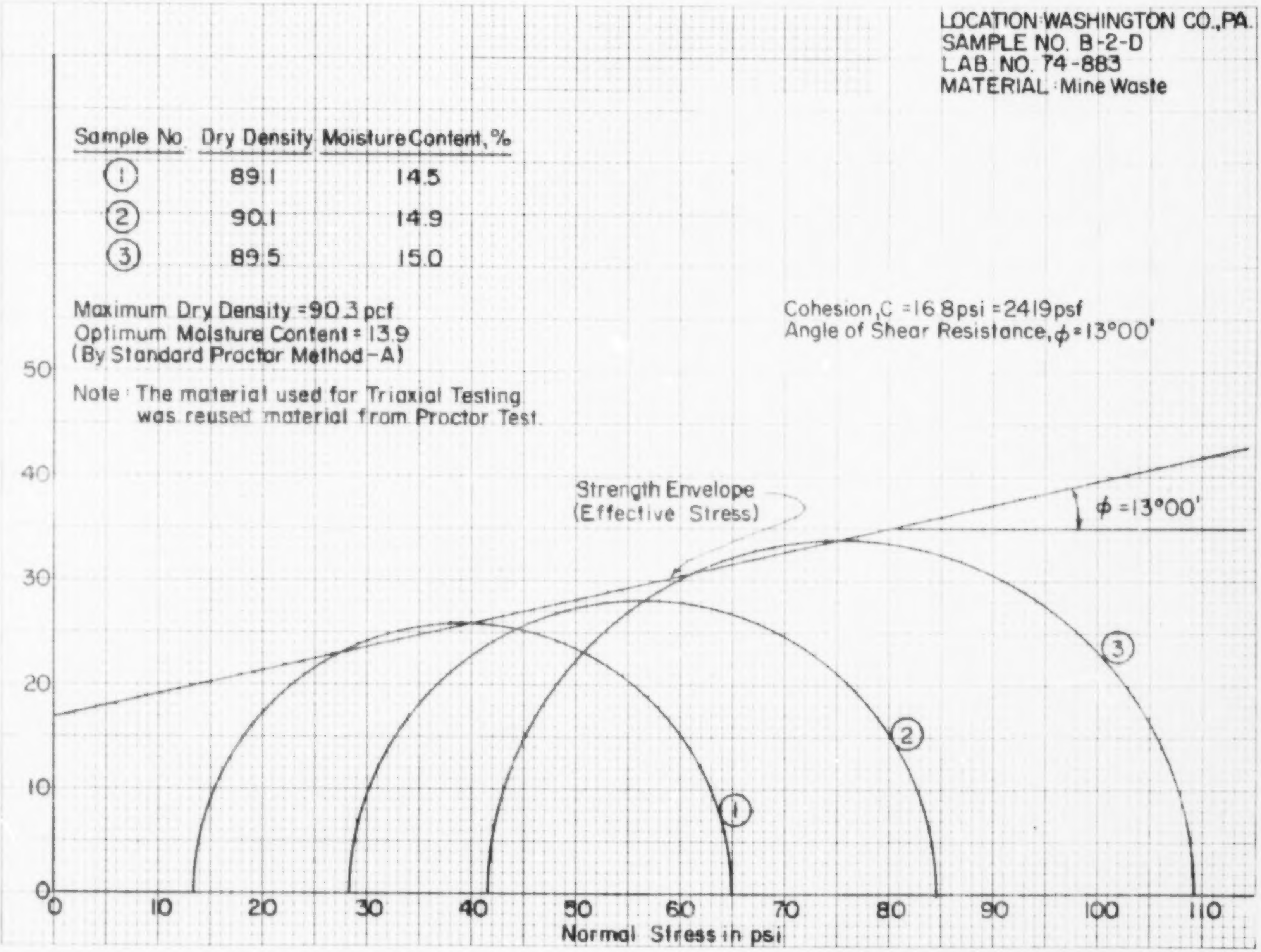
Maximum Dry Density = 91.6 pcf
Optimum Moisture Content = 13.3 %
(By Standard Proctor Method A)

Note: The material used for Triaxial Testing was reused material from Proctor Test.

Cohesion, C = 6.0 psi = 864 psf
Angle of Shear Resistance, ϕ = 24°00'

Shear Stress in psi
0
20
40
60
80
100
Normal Stress in psi
0
20
40
60
80
100
120
140
160
180
200
①
②
③
Strength Envelope
(Total Stress)
ϕ = 24°00'


LOCATION: WASHINGTON CO, PA.
SAMPLE NO: B-1-D
LAB NO: 74-881
MATERIAL: Mine Waste
σ_3 = 45 psi
σ_3 = 30 psi
σ_3 = 15 psi
③
②
①
σ_3 Confining Pressure
Deviator Stress, $\sigma_1 - \sigma_3$ in psi
0
20
40
60
80
100
120
140
Strain in %
0
2
4
6
8
10
12
14
16
18
20



LOCATION: WASHINGTON CO., PA.
SAMPLE NO. B-2-D
LAB. NO. 74-883
MATERIAL: Mine Waste

Sample No.	Dry Density	Moisture Content, %
①	89.1	14.5
②	90.1	14.9
③	89.5	15.0

Maximum Dry Density = 90.3 pcf
Optimum Moisture Content = 13.9
(By Standard Proctor Method – A)

Note: The material used for Triaxial Testing was reused material from Proctor Test.

Cohesion, C = 16.8 psi = 2419 psf
Angle of Shear Resistance, $\phi = 13°00'$

Strength Envelope
(Effective Stress)
$\phi = 13°00'$
①
②
③
0
10
20
30
40
50
0
10
20
30
40
50
60
70
80
90
100
110
Normal Stress in psi

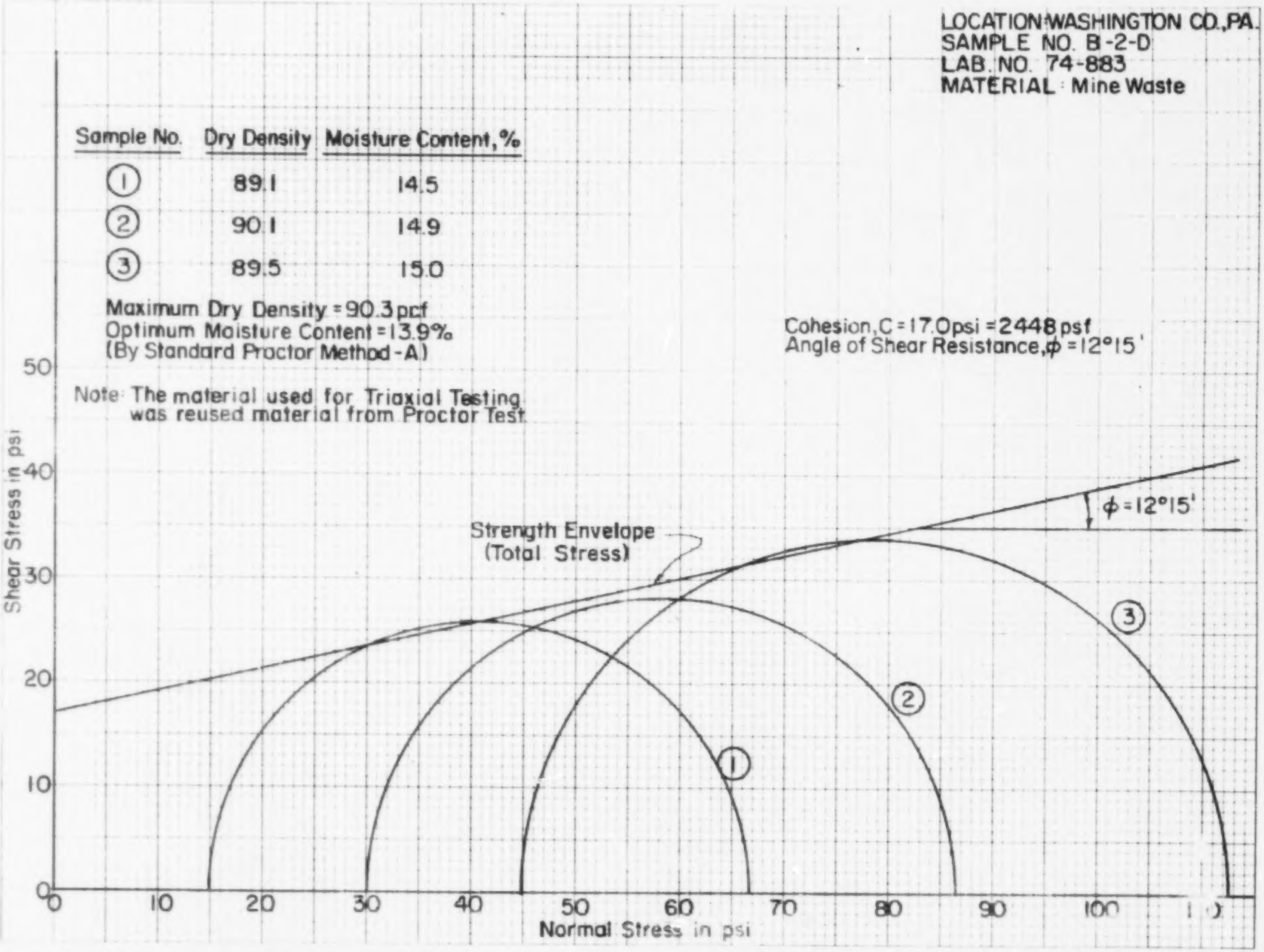
LOCATION:WASHINGTON CO.,PA.
SAMPLE NO. B-2-D
LAB. NO. 74-883
MATERIAL : Mine Waste

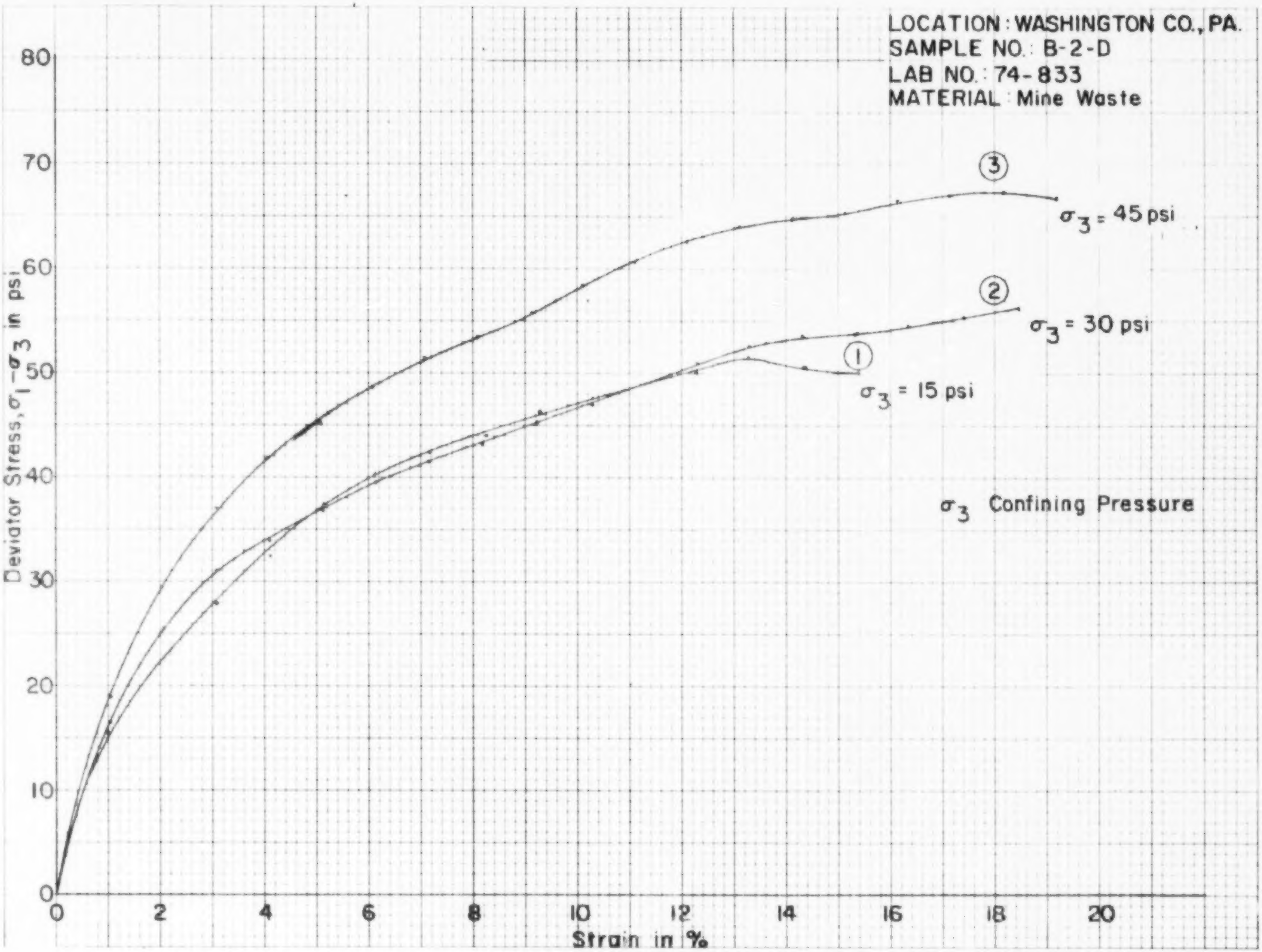
Sample No.	Dry Density	Moisture Content, %
①	89.1	14.5
②	90.1	14.9
③	89.5	15.0

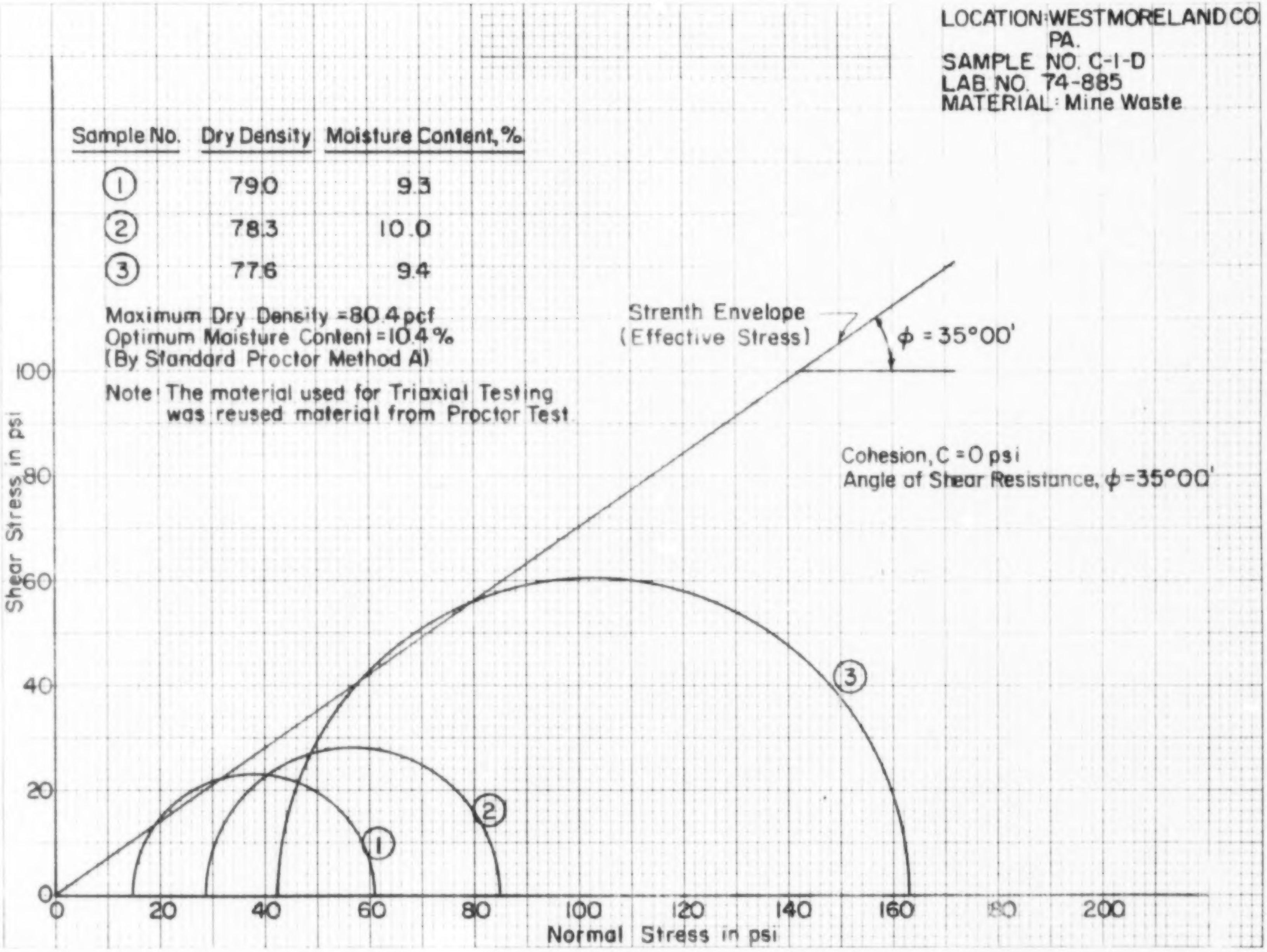
Maximum Dry Density = 90.3 pcf
Optimum Moisture Content = 13.9%
(By Standard Proctor Method - A)

Note: The material used for Triaxial Testing was reused material from Proctor Test.

Cohesion, C = 17.0 psi = 2448 psf
Angle of Shear Resistance, ϕ = 12°15'




LOCATION: WASHINGTON CO., PA.
SAMPLE NO.: B-2-D
LAB NO.: 74-833
MATERIAL: Mine Waste
③ σ_3 = 45 psi
② σ_3 = 30 psi
① σ_3 = 15 psi
σ_3 Confining Pressure
Deviator Stress, $\sigma_1 - \sigma_3$ in psi
0
10
20
30
40
50
60
70
80
Strain in %
0
2
4
6
8
10
12
14
16
18
20



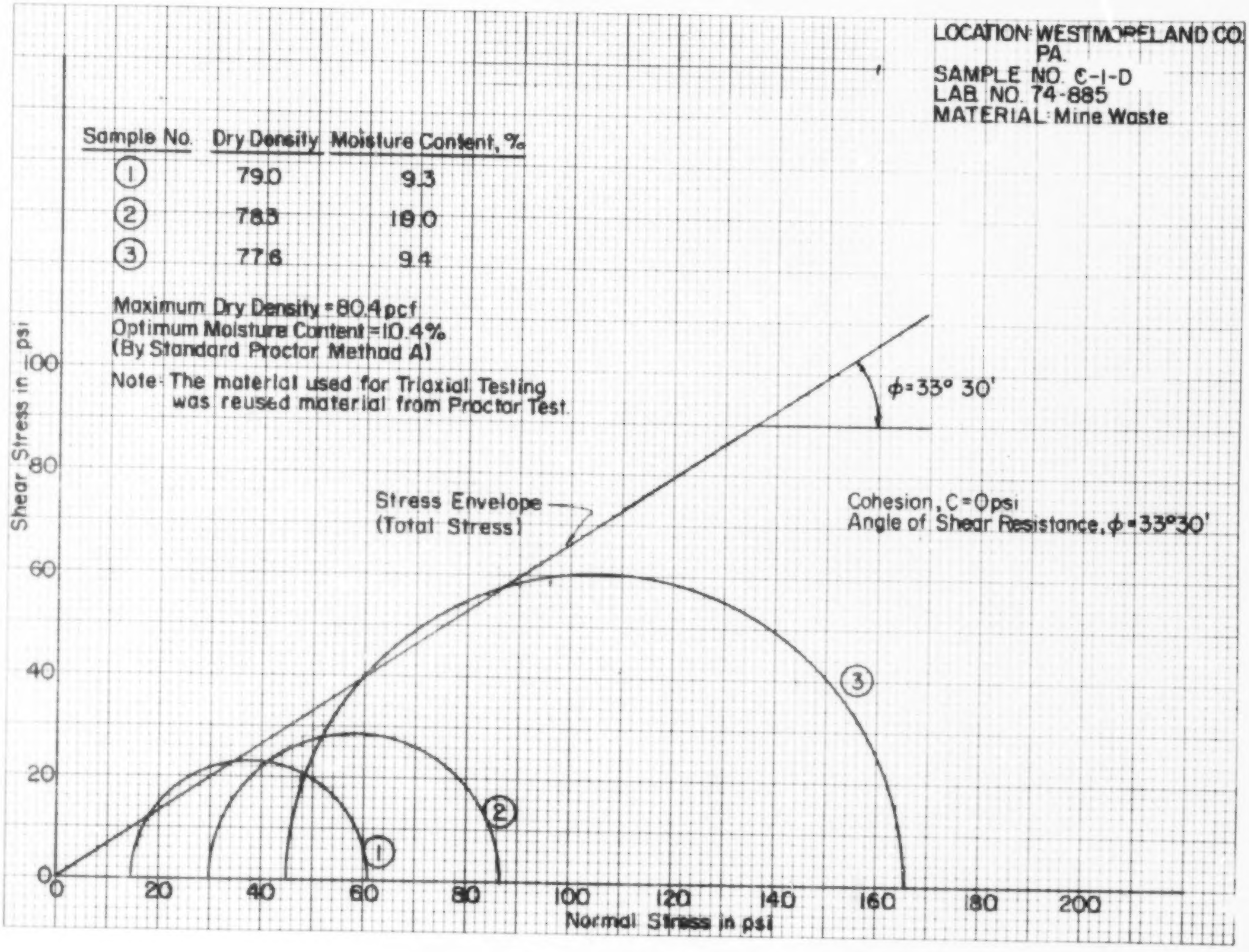
LOCATION: WESTMORELAND CO.
PA.
SAMPLE NO. C-1-D
LAB. NO. 74-885
MATERIAL: Mine Waste

Sample No.	Dry Density	Moisture Content, %
①	79.0	9.3
②	78.3	10.0
③	77.6	9.4

Maximum Dry Density = 80.4 pcf
Optimum Moisture Content = 10.4 %
(By Standard Proctor Method A)

Note: The material used for Triaxial Testing was reused material from Proctor Test

Cohesion, C = 0 psi
Angle of Shear Resistance, ϕ = 35°00'



LOCATION: WESTMORELAND CO.
PA.
SAMPLE NO. C-1-D
LAB. NO. 74-885
MATERIAL: Mine Waste

Sample No.	Dry Density	Moisture Content, %
①	79.0	9.3
②	78.3	10.0
③	77.6	9.4

Maximum Dry Density = 80.4 pcf
Optimum Moisture Content = 10.4%
(By Standard Proctor Method A)

Note: The material used for Triaxial Testing was reused material from Proctor Test.

Cohesion, C = 0 psi
Angle of Shear Resistance, φ = 33°30'

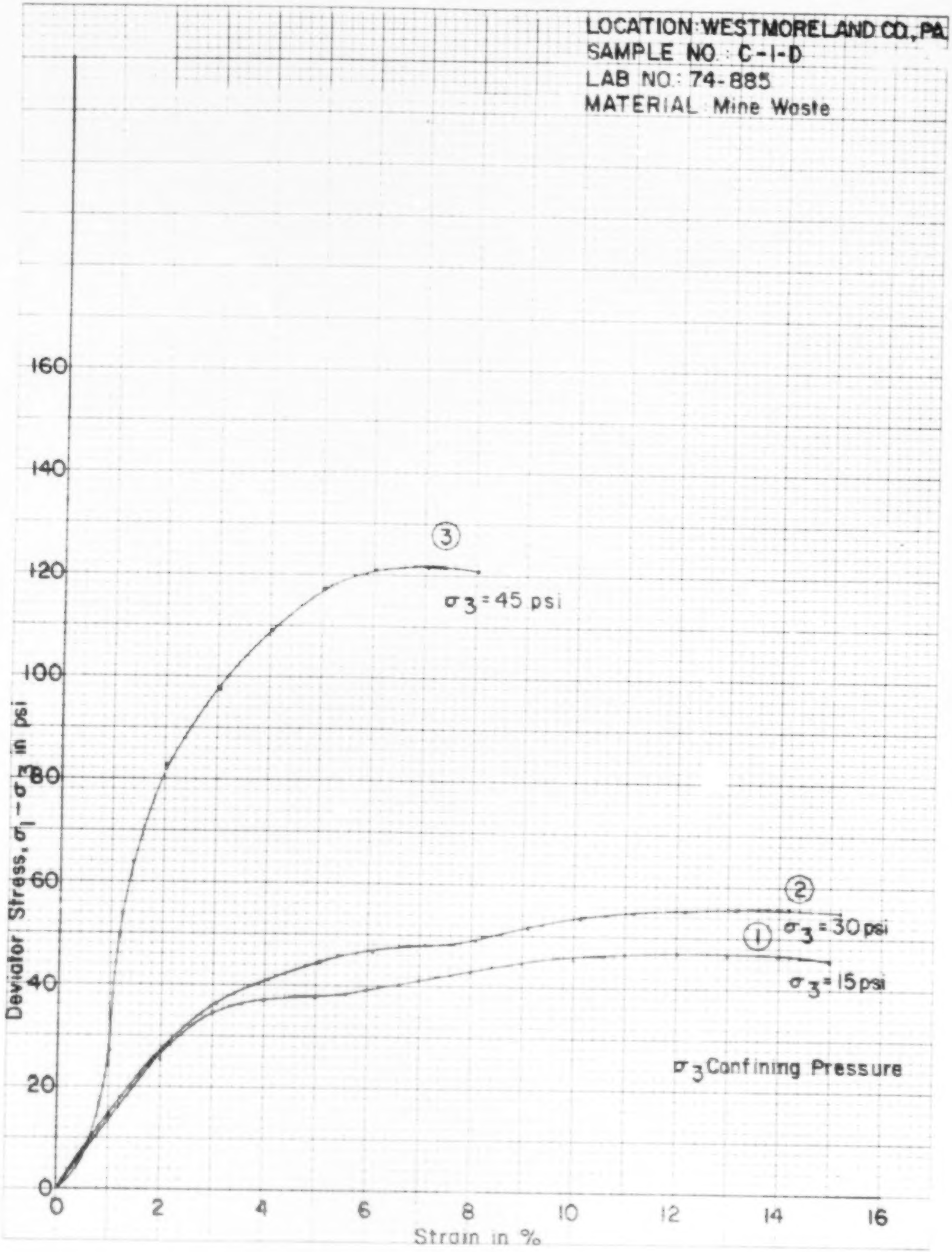

LOCATION: WESTMORELAND CO., PA.
SAMPLE NO.: C-1-D
LAB NO.: 74-885
MATERIAL: Mine Waste
③
σ3 = 45 psi
②
σ3 = 30 psi
①
σ3 = 15 psi
σ3 Confining Pressure
Deviator Stress, σ1 − σ3 in psi
0
20
40
60
80
100
120
140
160
Strain in %
0
2
4
6
8
10
12
14
16

EXHIBIT E

Consolidation and Permeability Tests

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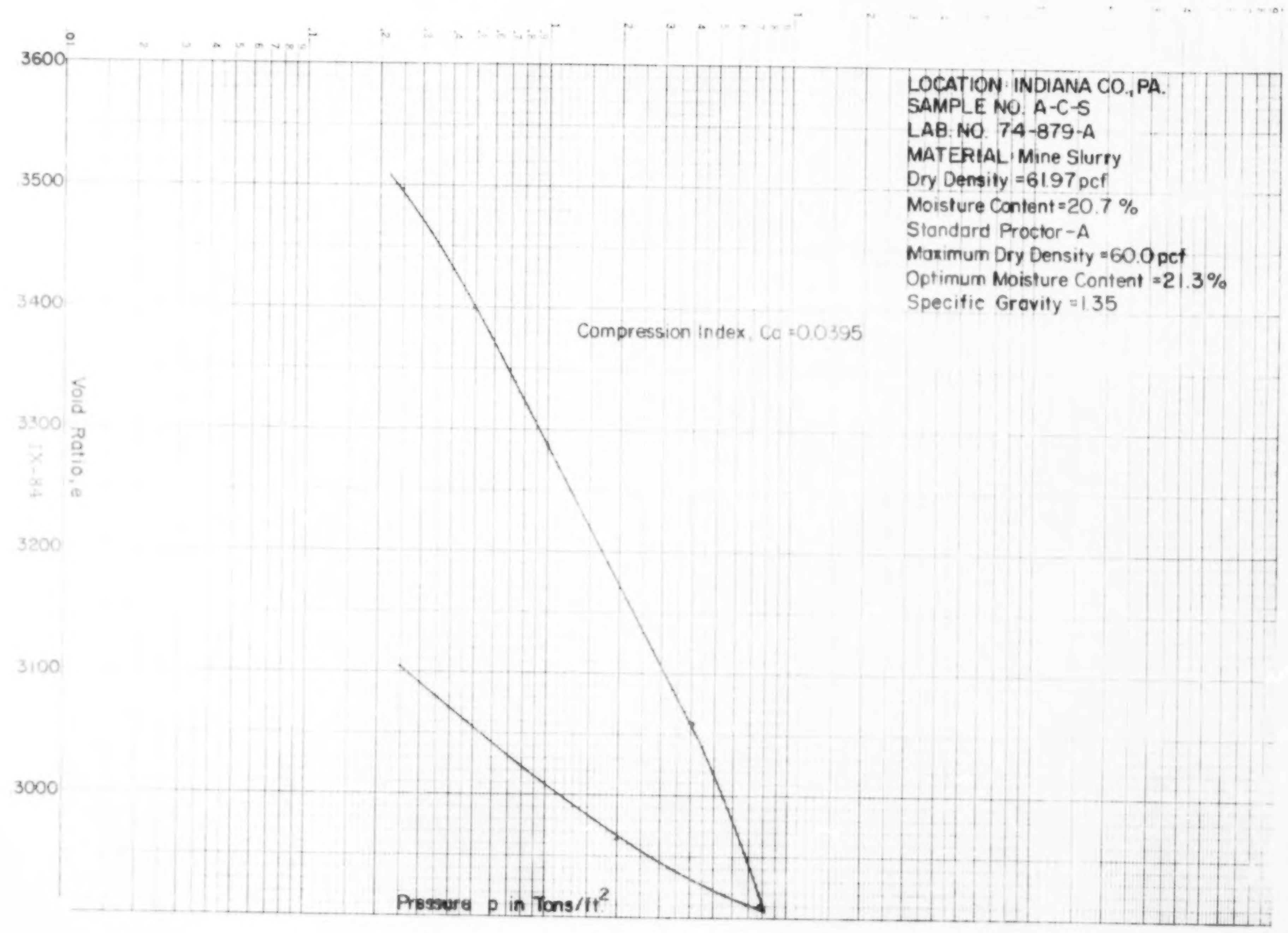
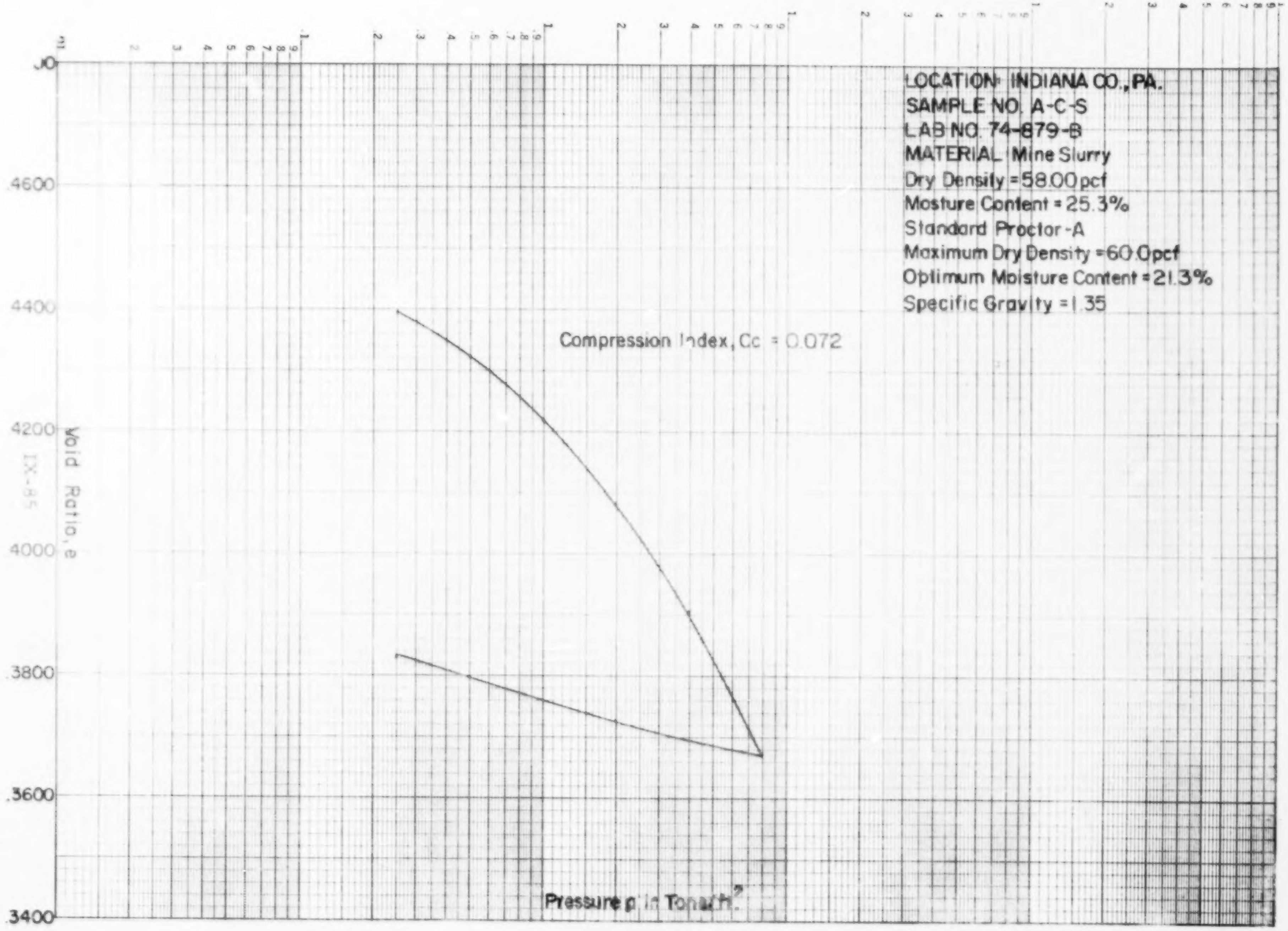
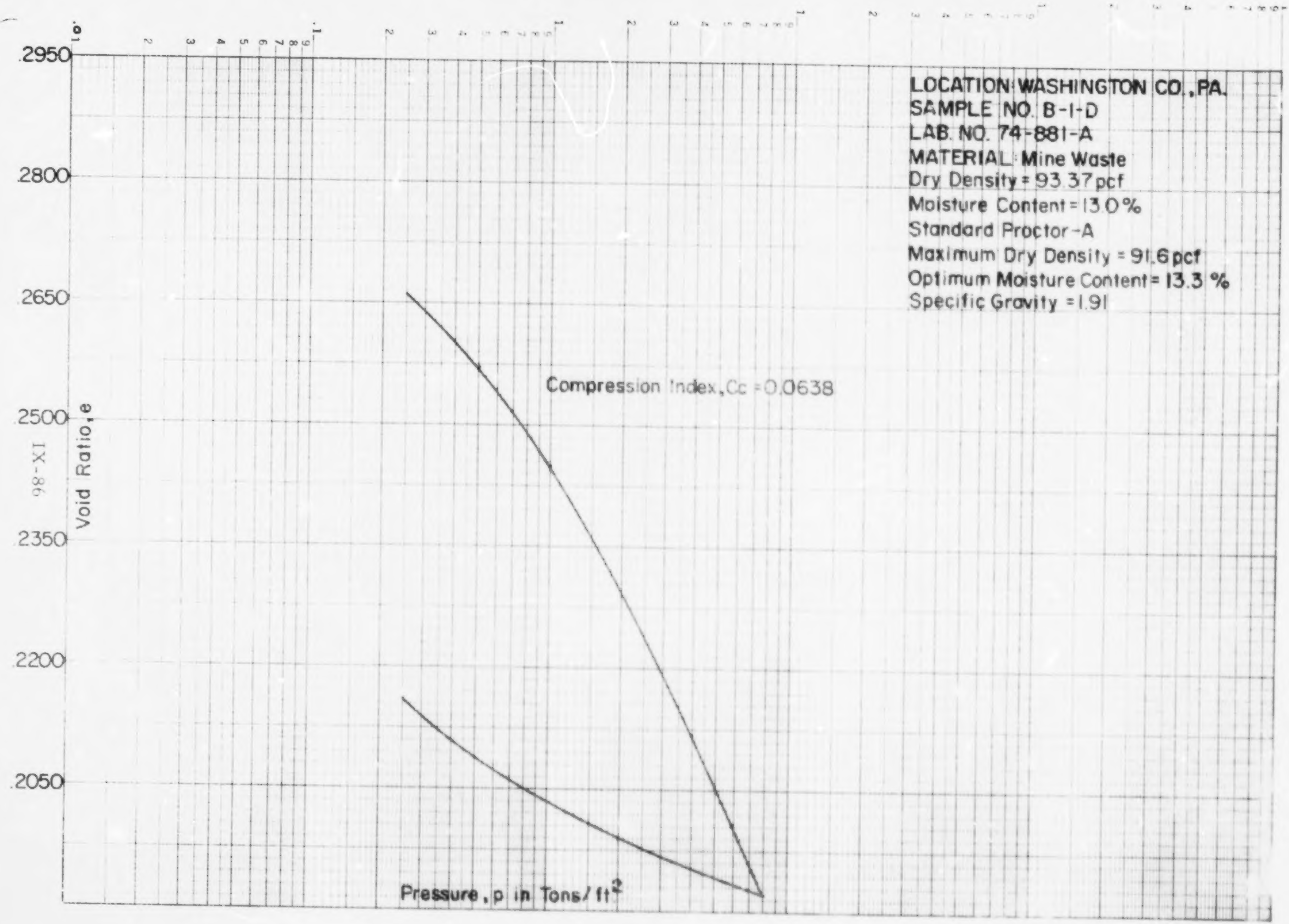
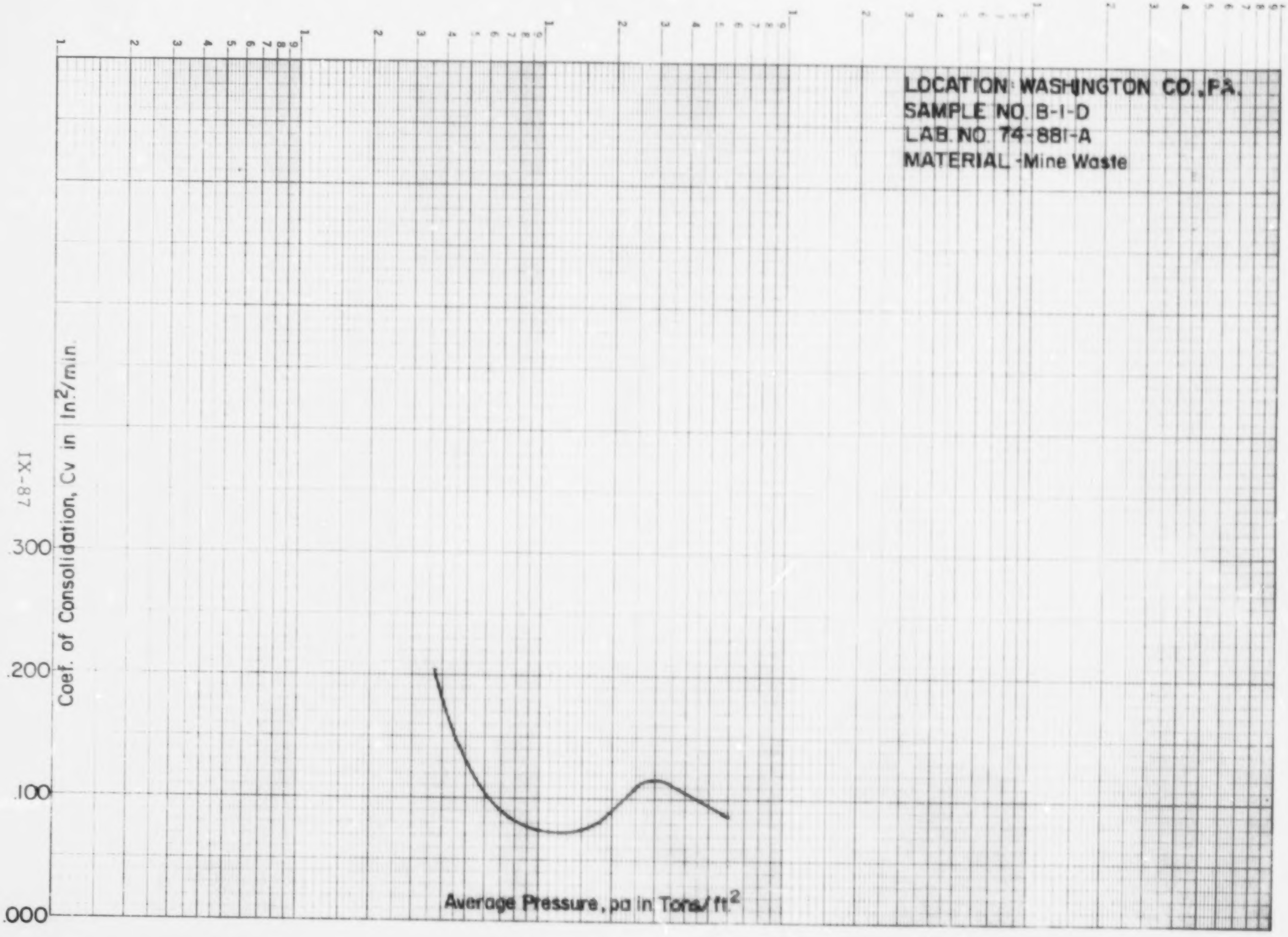
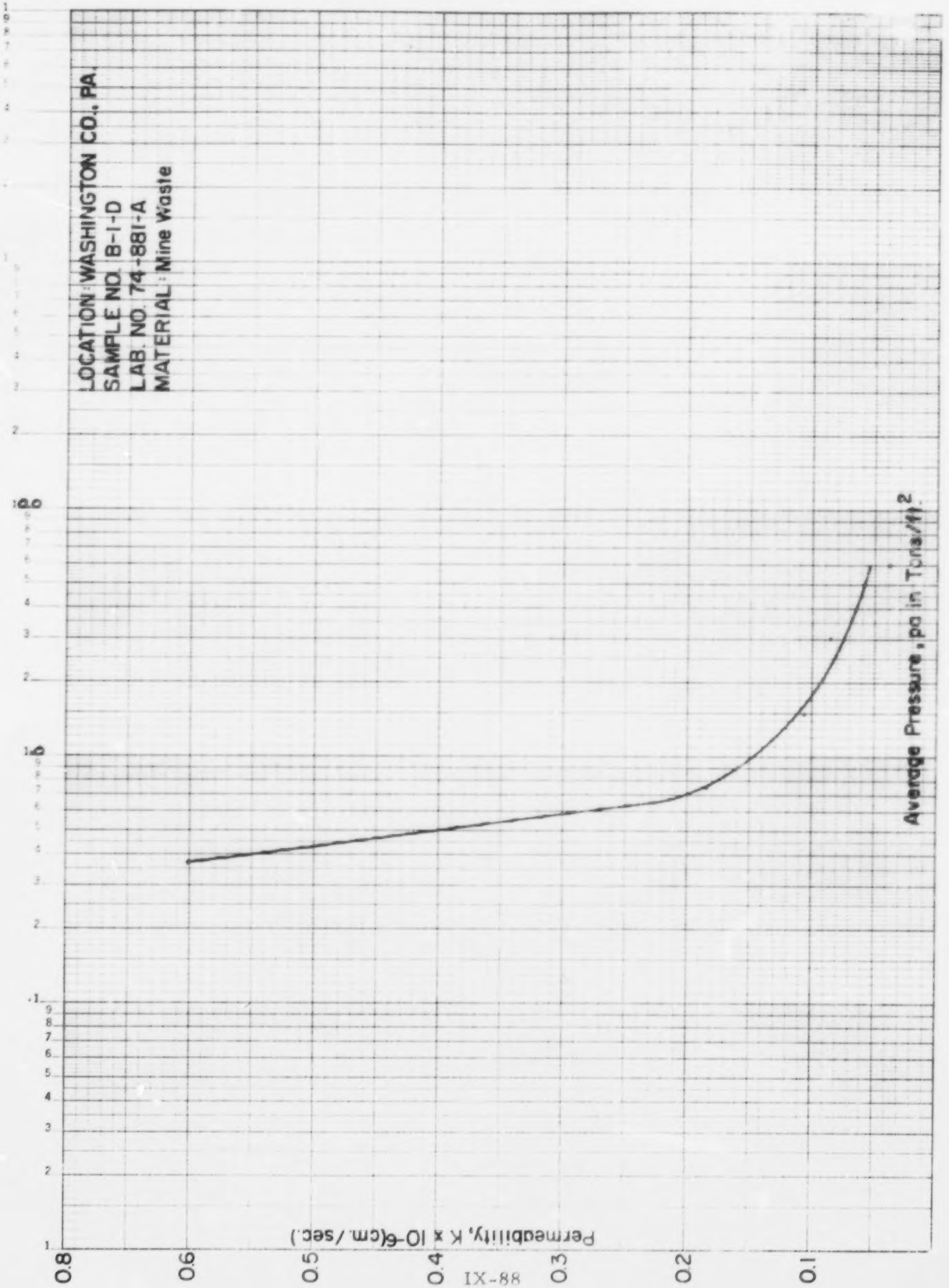
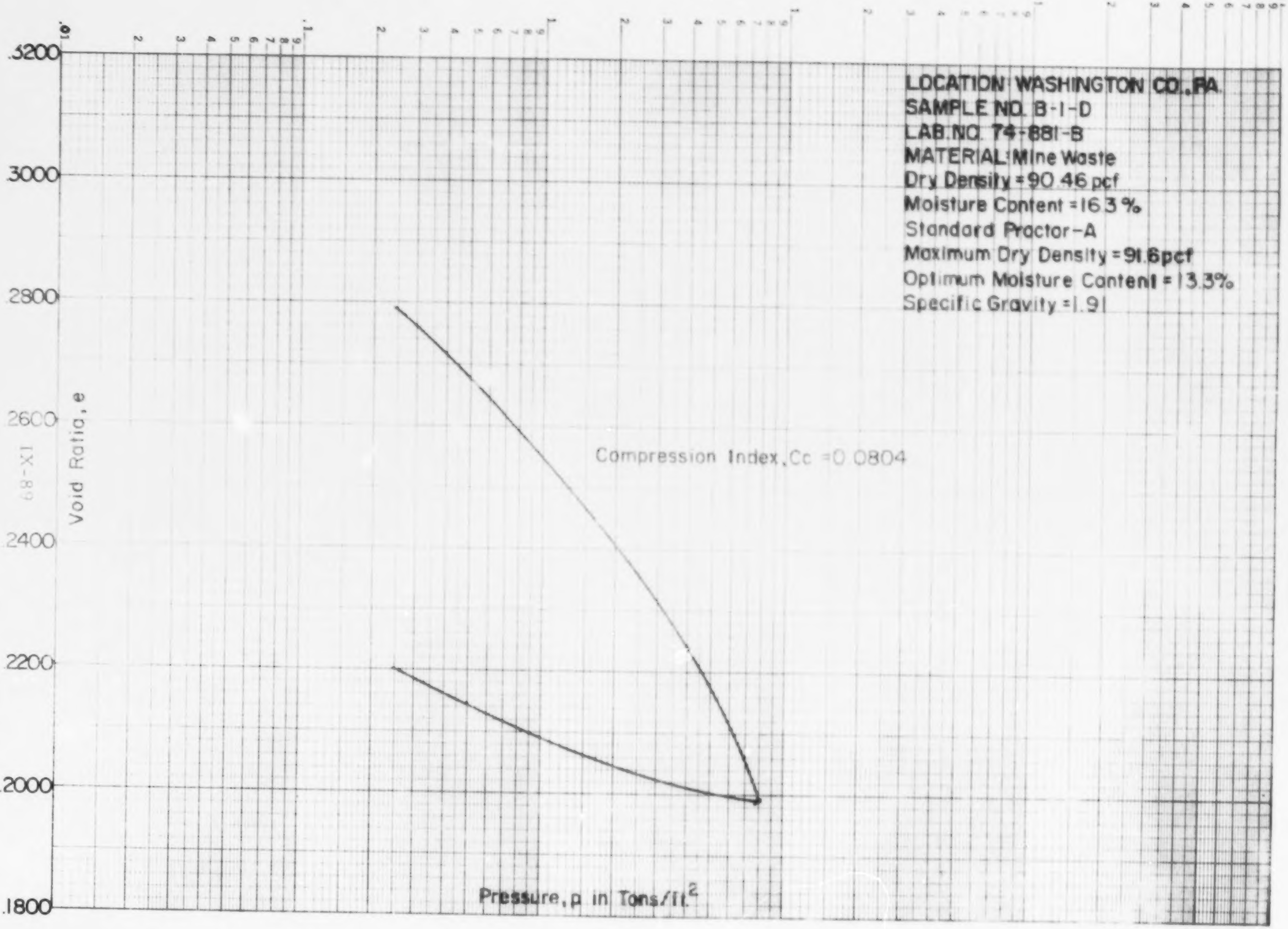

LOCATION: INDIANA CO., PA.
SAMPLE NO. A-C-S
LAB. NO. 74-879-A
MATERIAL: Mine Slurry
Dry Density =61.97 pcf
Moisture Content =20.7 %
Standard Proctor - A
Maximum Dry Density =60.0 pcf
Optimum Moisture Content =21.3%
Specific Gravity =1.35
Compression Index, Cc =0.0395
Void Ratio, e
Pressure p in Tons/ft^2
3600
3500
3400
3300
3200
3100
3000
.01
.1
1
10


LOCATION: INDIANA CO., PA.
SAMPLE NO. A-C-S
LAB NO. 74-879-B
MATERIAL: Mine Slurry
Dry Density = 58.00 pcf
Mosture Content = 25.3%
Standard Proctor - A
Maximum Dry Density = 60.0 pcf
Optimum Moisture Content = 21.3%
Specific Gravity = 1.35


LOCATION: WASHINGTON CO., PA.
SAMPLE NO. B-1-D
LAB. NO. 74-881-A
MATERIAL: Mine Waste
Dry Density = 93.37 pcf
Moisture Content = 13.0 %
Standard Proctor-A
Maximum Dry Density = 91.6 pcf
Optimum Moisture Content = 13.3 %
Specific Gravity = 1.91
Compression Index, Cc = 0.0638
Void Ratio, e
Pressure, p in Tons/ft²
.2950
.2800
.2650
.2500
.2350
.2200
.2050
.01
.1
1

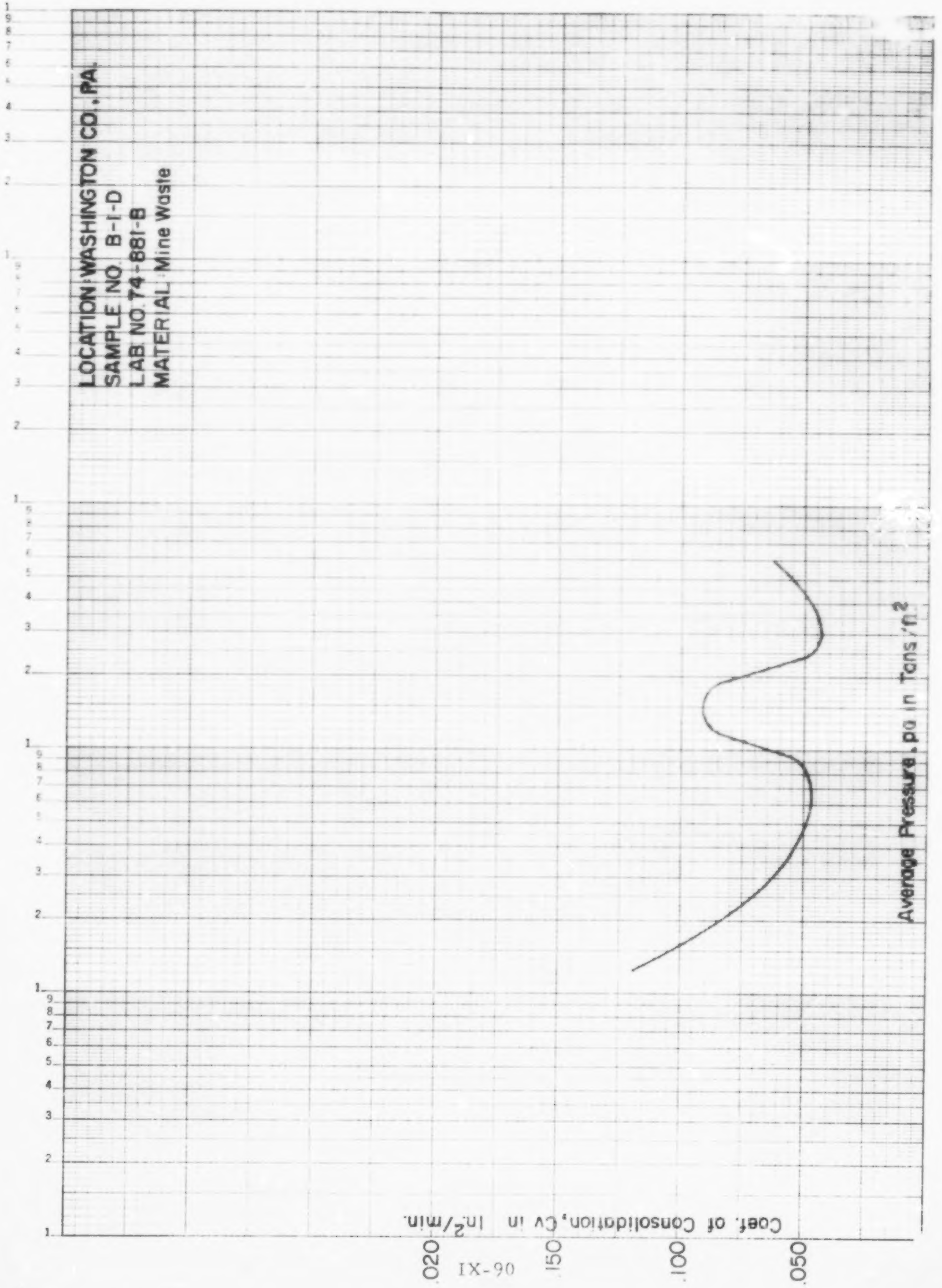

LOCATION: WASHINGTON CO., PA.
SAMPLE NO. B-1-D
LAB. NO. 74-881-A
MATERIAL -Mine Waste
Coef. of Consolidation, Cv in In.^{2}/min.
.300
.200
.100
.000
Average Pressure, pa in Tons/ ft.^{2}
1
2
3
4
5
6
7
8
9

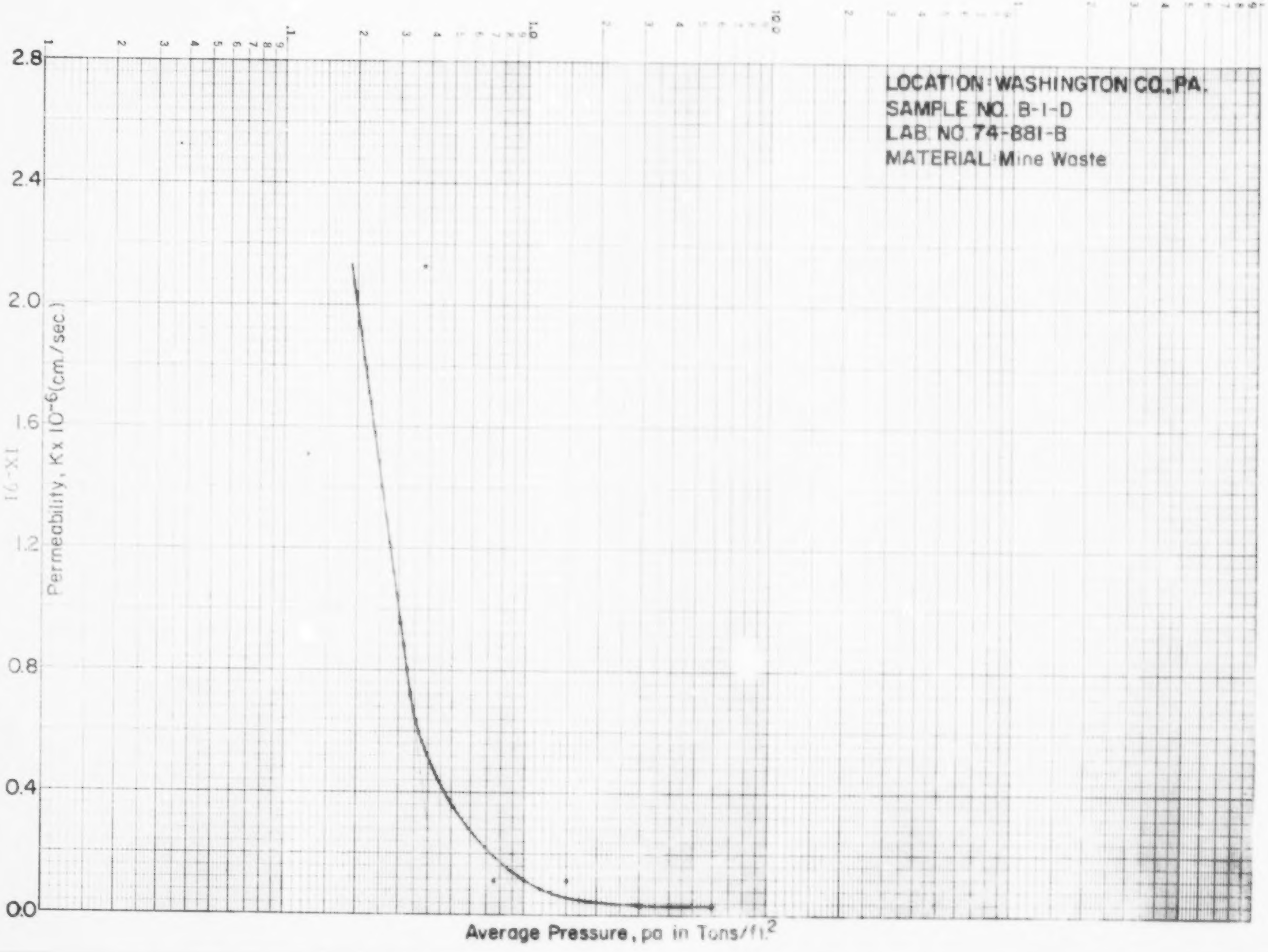

LOCATION: WASHINGTON CO., PA.
SAMPLE NO. B-1-D
LAB. NO. 74-881-A
MATERIAL: Mine Waste
Average Pressure, pa in Tons/ft²
Permeability, K x 10-6(cm./sec.)
0.8
0.6
0.5
0.4
0.3
0.2
0.1

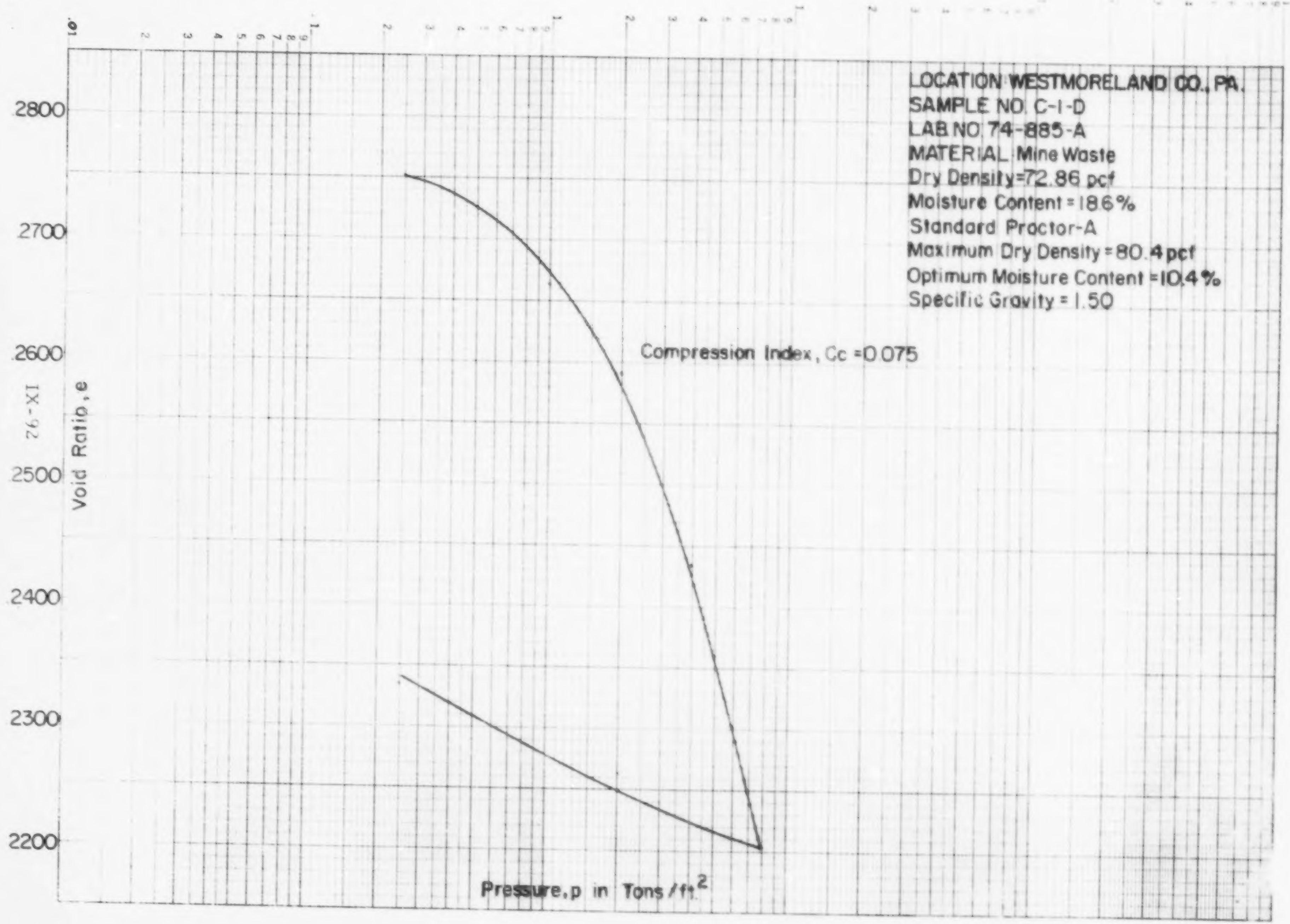


LOCATION: WASHINGTON CO., PA.
SAMPLE NO. B-1-D
LAB.NO. 74-881-B
MATERIAL: Mine Waste
Dry Density = 90.46 pcf
Moisture Content = 16.3 %
Standard Proctor-A
Maximum Dry Density = 91.6pcf
Optimum Moisture Content = 13.3%
Specific Gravity = 1.91

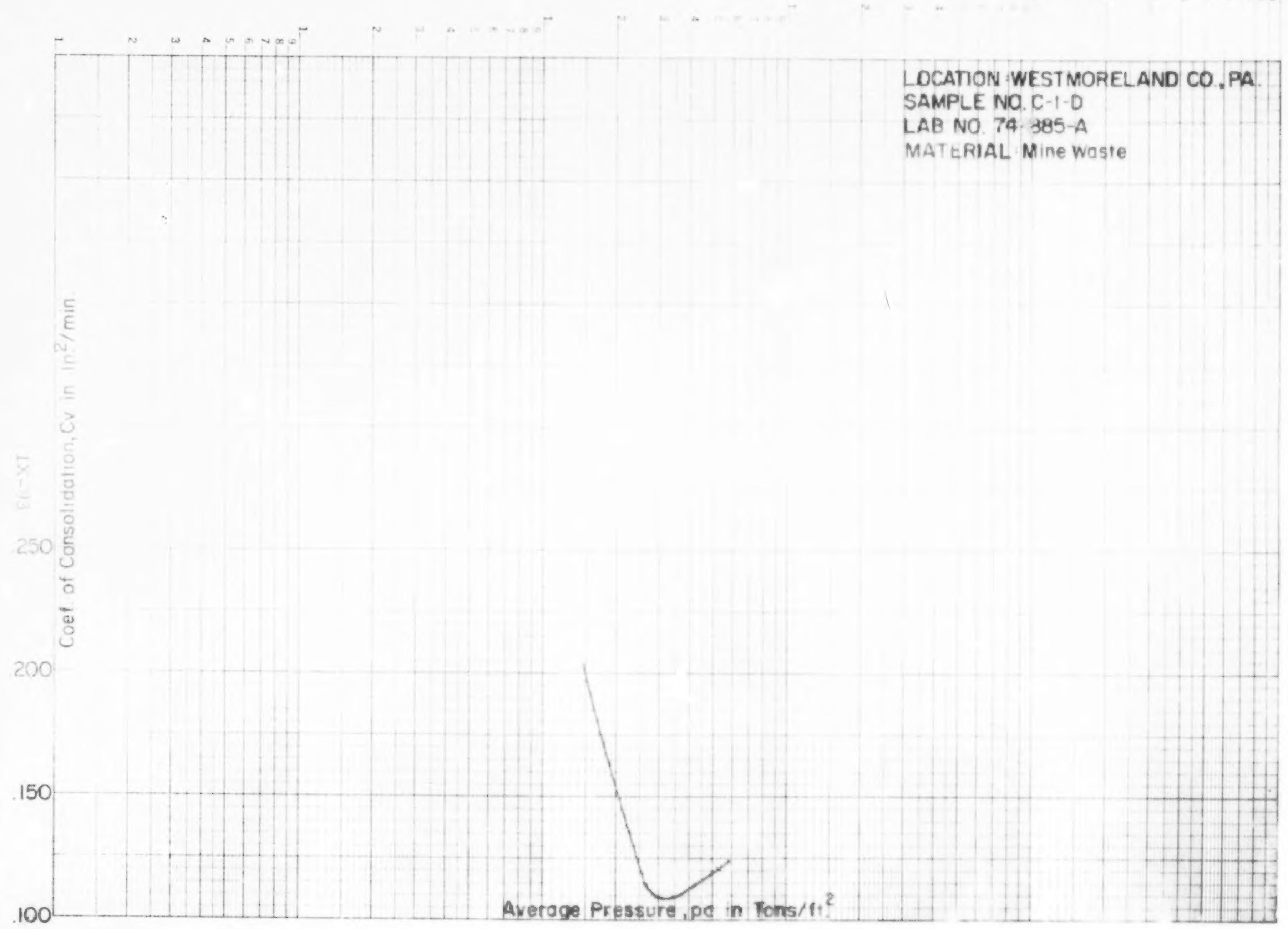
Compression Index, Cc = 0.0804

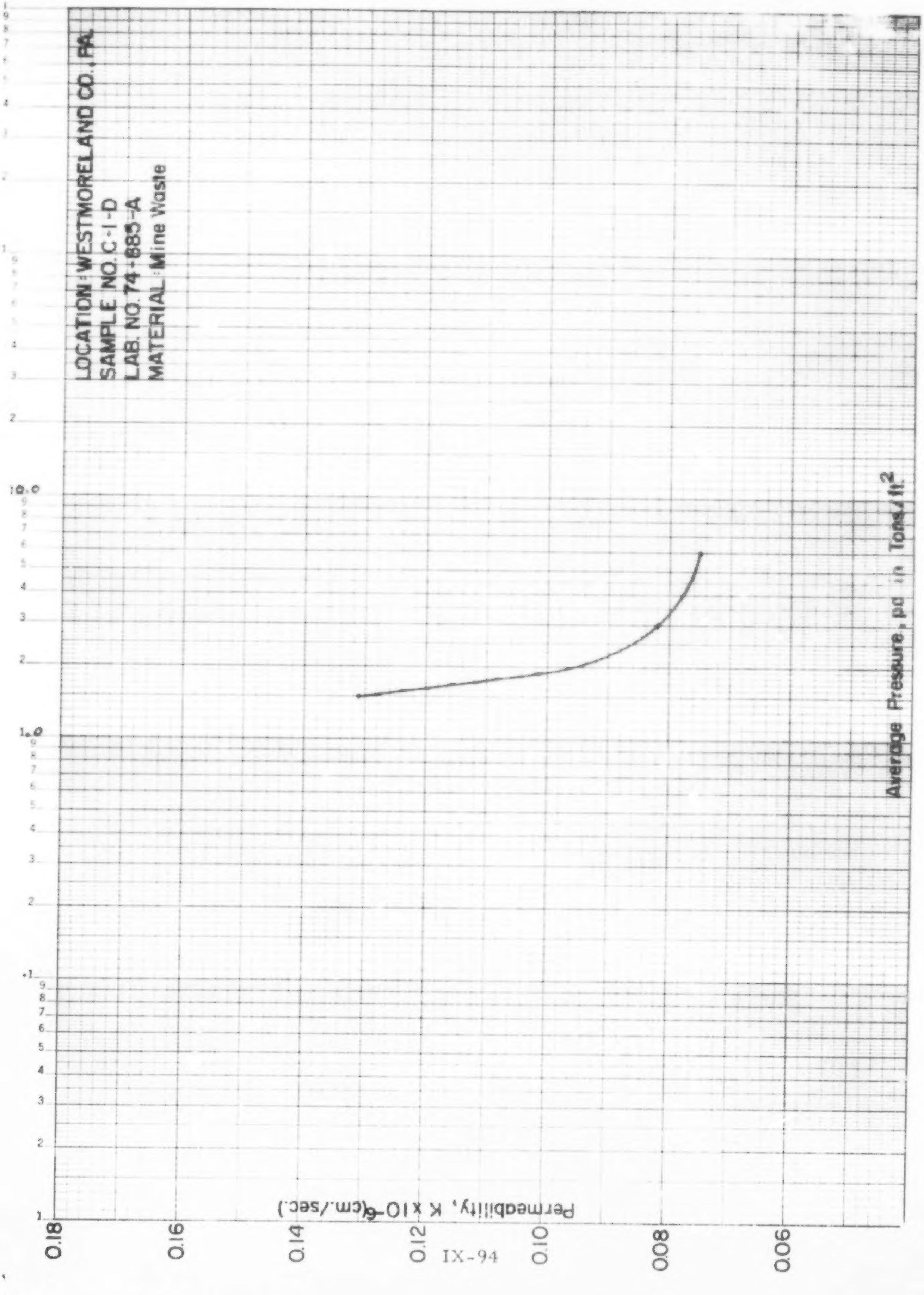

LOCATION: WASHINGTON CO., PA.
SAMPLE NO. B-1-D
LAB NO. 74-881-B
MATERIAL: Mine Waste
Average Pressure, pa in Tons/ft²
Coef. of Consolidation, Cv in in²/min.
.200
.150
.100
.050
1
9
8
7
6
5
4
3
2

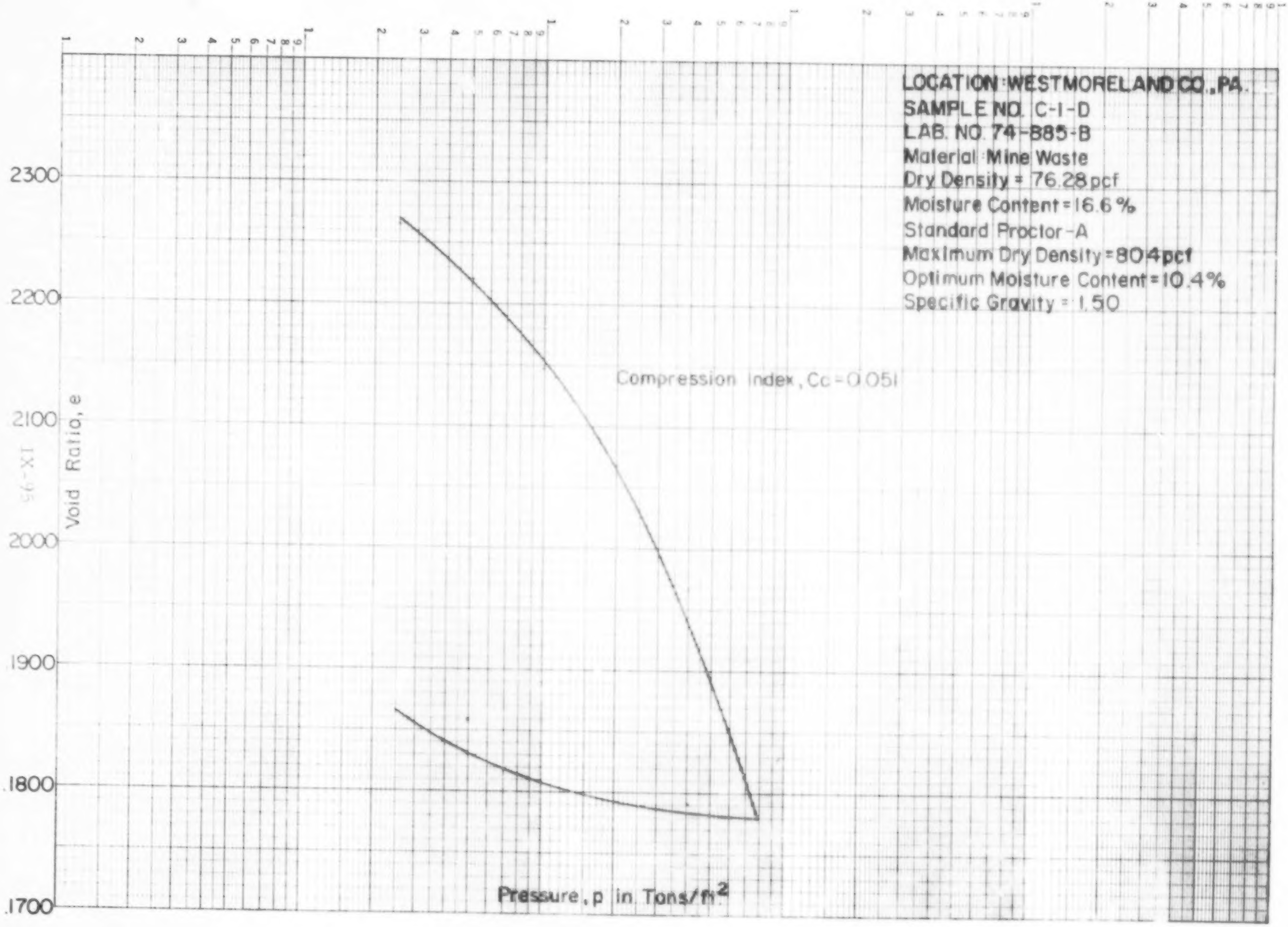

LOCATION: WASHINGTON CO., PA.
SAMPLE NO. B-1-D
LAB. NO. 74-881-B
MATERIAL: Mine Waste
Permeability, K x 10⁻⁶(cm./sec.)
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
Average Pressure, pa in Tons/ft.²
.1
1.0
10.0

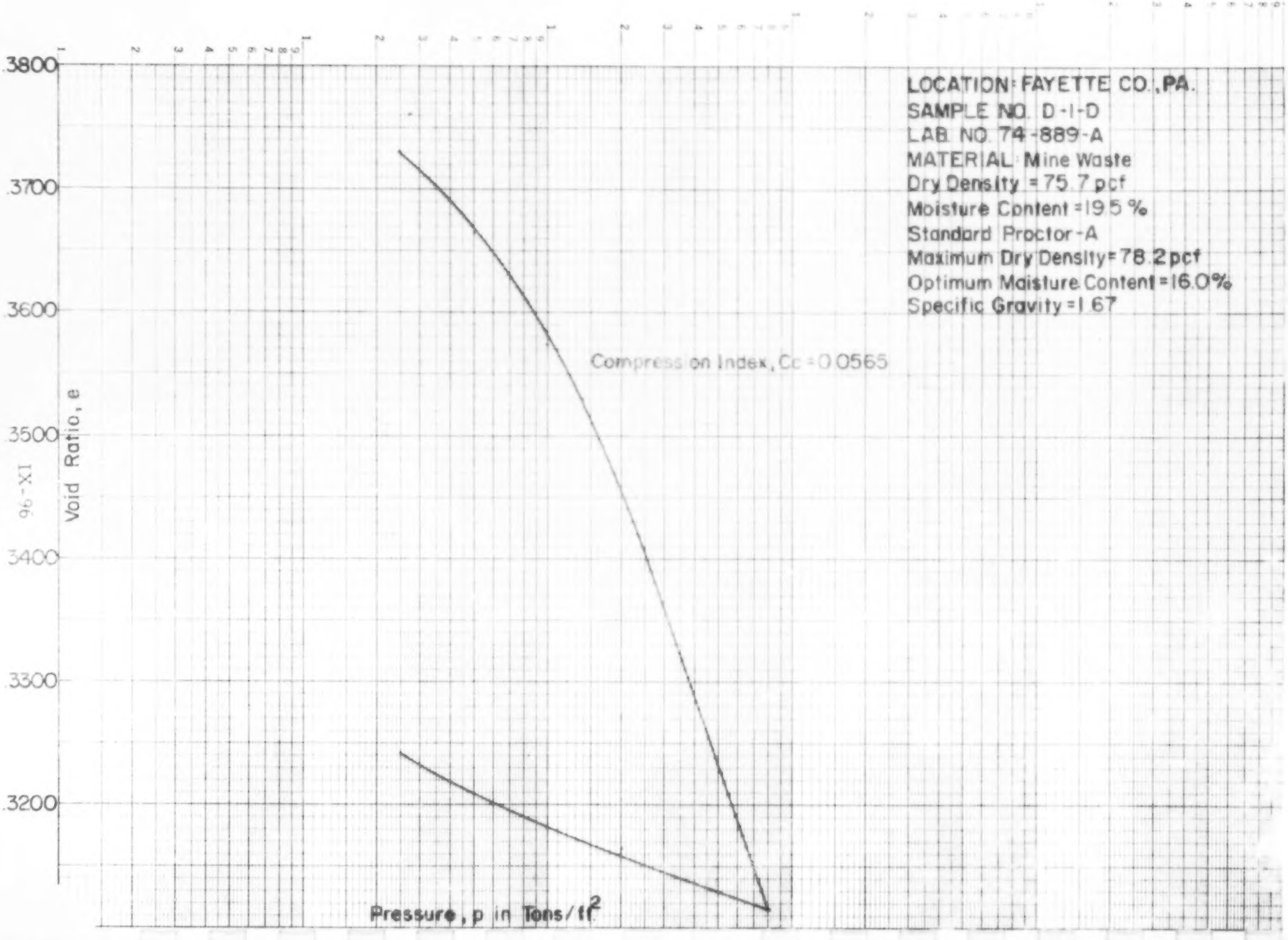

LOCATION WESTMORELAND CO., PA.
SAMPLE NO. C-1-D
LAB NO. 74-885-A
MATERIAL Mine Waste
Dry Density=72.86 pcf
Moisture Content = 18.6%
Standard Proctor-A
Maximum Dry Density = 80.4 pcf
Optimum Moisture Content = 10.4%
Specific Gravity = 1.50

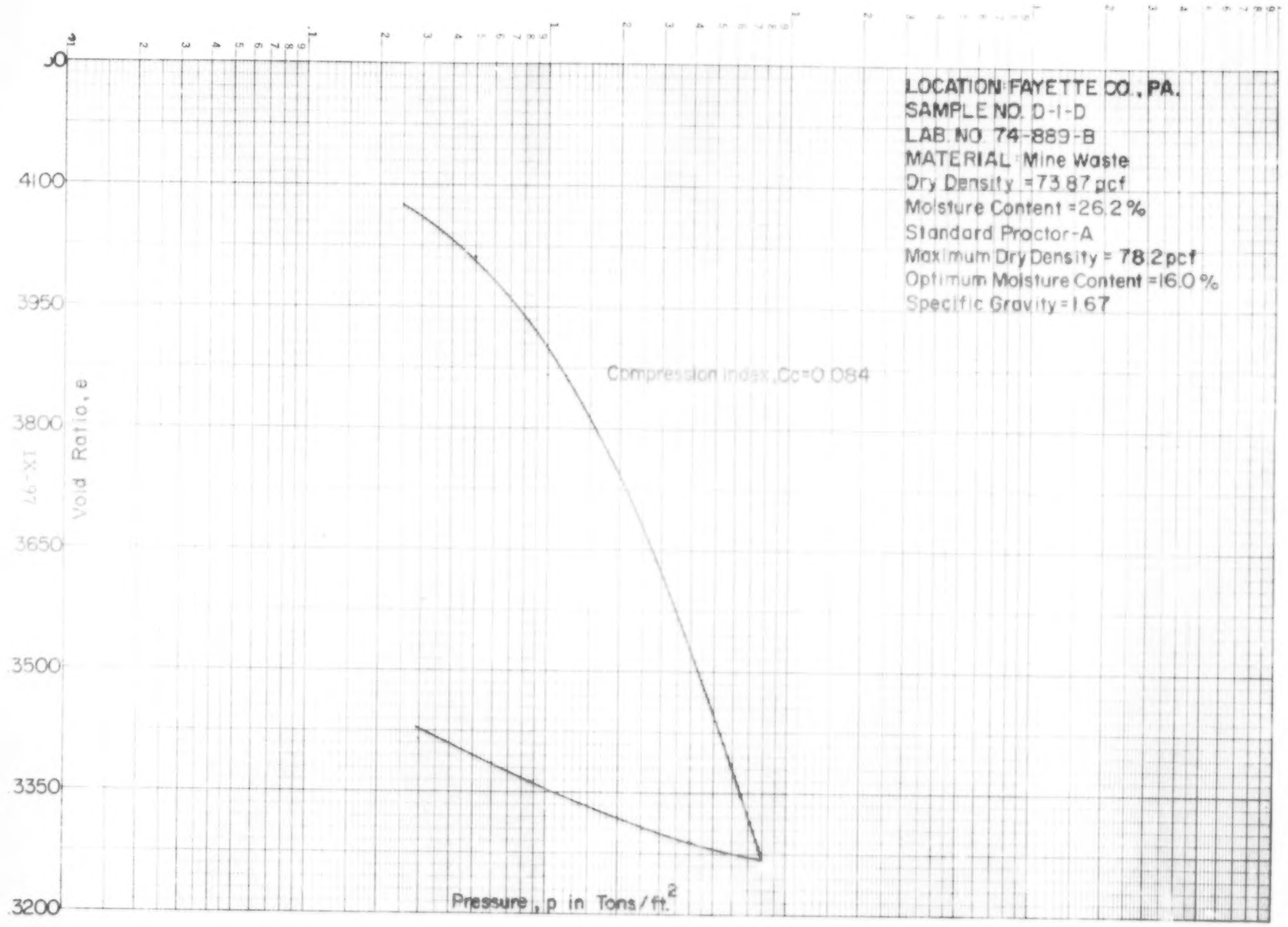
Compression Index, Cc = 0.075


LOCATION: WESTMORELAND CO., PA.
SAMPLE NO. C-1-D
LAB NO. 74-885-A
MATERIAL: Mine Waste
Coef. of Consolidation, Cv in in²/min.
.250
.200
.150
.100
Average Pressure, pc in Tons/ft²
1
2
3
4
5
6
7
8
9
1

LOCATION: WESTMORELAND CO., PA.
SAMPLE NO. C-1-D
LAB. NO. 74-885-A
MATERIAL: Mine Waste
Average Pressure, pa in Tons/ft^2
Permeability, K x 10^{-6}(cm./sec.)
0.18
0.16
0.14
0.12
0.10
0.08
0.06
.1
1.0
10.0


LOCATION: WESTMORELAND CO., PA.
SAMPLE NO. C-1-D
LAB. NO. 74-885-B
Material: Mine Waste
Dry Density = 76.28 pcf
Moisture Content = 16.6 %
Standard Proctor-A
Maximum Dry Density = 80.4 pcf
Optimum Moisture Content = 10.4%
Specific Gravity = 1.50
Compression Index, Cc = 0.051
Void Ratio, e
Pressure, p in Tons/ft²
.2300
.2200
.2100
.2000
.1900
.1800
.1700

 LOCATION: FAYETTE CO., PA.
SAMPLE NO. D-1-D
LAB. NO. 74-889-A
MATERIAL: Mine Waste
Dry Density = 75.7 pcf
Moisture Content = 19.5 %
Standard Proctor-A
Maximum Dry Density = 78.2 pcf
Optimum Moisture Content = 16.0%
Specific Gravity = 1.67
Compression Index, Cc = 0.0565
Void Ratio, e
Pressure, p in Tons/ft^2
.3800
.3700
.3600
.3500
.3400
.3300
.3200


LOCATION: FAYETTE CO., PA.
SAMPLE NO. D-1-D
LAB. NO. 74-889-B
MATERIAL: Mine Waste
Dry Density =73.87 pcf
Moisture Content =26.2 %
Standard Proctor-A
Maximum Dry Density = 78.2 pcf
Optimum Moisture Content =16.0 %
Specific Gravity =1.67
Compression Index, Cc=0.084
Void Ratio, e
.4100
.3950
.3800
.3650
.3500
.3350
.3200
Pressure, p in Tons/ft.²
.1
1
2
3
4
5
6
7
8
9

MICHAEL BAKER, JR., INC.
Beaver, Pennsylvania

Geotechnical Engineering Department
Falling Head Permeability Test

Location Indiana Co., Pa.
Boring No. A-C-S Depth 0.5'-1.0
Sample No. 74-879
Specific Gravity, G_s 1.35
Wet Wt. of Sample 2.40 lbs.
Dry Wt. of Sample W_s 1.99 lbs.
902.7 gms.

Specimen Measurements
Diameter 4"
Circumference 12.56 in.
Area, A 81.1 cm^2
Length, L 11.61 cm
Volume of Sample 941.6 cc.

Test No. 1
Date 11-1-74
Tested By RWD

Volume of Solid Material $V_s = W_s/G_s$ 668.7 cc

Void Ratio of Sample $e = \frac{V - V_s}{V_s} = \frac{941.6-668.7}{668.7} = \frac{272.9}{668.7} = .4081$

Dry Density = 59.8 pcf Moisture Content = 20.5%

Test Data

Time	Elapsed Time (t) Sec.	Quantity Q cc	Area of Burette a cm^2	h_0	h_1	$Log_{10}h_0/h_1$	k cm/sec.
2:58	720	10.0	1.03	69.0	59.3	.05385	2.53 x 10-5
3:10				82.7	73.0		
3:17	840	12.0	1.017	69.8	58.0	.06595	2.62 x 10-5
3:31				83.5	71.7		
3:35	1320	10.2	1.03	68.3	58.4	.05576	1.43 x 10-5
3:47				82.0	72.1		
3:50	720	10.4	1.02	68.9	58.7	.05690	2.64 x 10-5
4:02				82.6	72.4		
4:05	840	10.2	1.01	56.2	46.1	.06744	2.66 x 10-5
4:19				69.9	59.8		
10:21	720	17.5	1.02	69.8	52.7	.09934	4.64 x 10-5
10:33				83.5	66.4		
11:25	960	22.0	1.01	69.5	47.8	.13098	4.55 x 10-5
11:41				83.2	61.5		
						Avg.	3.51 x 10-5

$K = 2.3 \frac{aL}{At} \quad Log_{10} \frac{ho}{h1}$

$a = \frac{Q}{h_1 - h_2}$

Remarks Mine slurry material. Test performed on reused material after Compaction Test.

MICHAEL BAKER, JR., INC.
Beaver, Pennsylvania

Geotechnical Engineering Department
Constant Head Permeability Test

Location Indiana Co., Pa.
Boring No. A-C-S Depth 0.5'-1.0'
Sample No. 74-879
Specific Gravity, G_s 1.35
Wet Wt. of Sample 2.49 lb.
Dry Wt. of Sample 889.0 gm.
Dry Density 58.8 pcf

Specimen Measurements
Diameter 4"
Area, A 81.1 cm^2
Length, L 11.61 cm
Volume of Sample 941.6 cm^3

Test No. 2
Date 11-4-74
Tested By KLT

Volume of Solid Material = $V_s = W_s/G_s$ = 658.5 cm^3
Void Ratio of Sample = $e = \frac{V - V_s}{V_s}$ = 0.43 = ______ = ______

Moisture Content = 27.1%

Start Time	Finish Time	Elapsed Time (t) sec	Quantity Q cc	Pressure Head H, cm	Rate Discharge q, cc/sec	K cm/sec
2:23	2:36	780	14.5	17.5	0.0186	1.52×10^{-4}
2:40	2:52	720	13.5	17.5	0.0187	1.53×10^{-4}
2:55	3:07	720	15.0	17.5	0.0208	1.70×10^{-4}
3:10	3:27	1,020	19.8	17.5	0.0194	1.59×10^{-4}
3:29	3:45	960	18.0	17.5	0.0187	1.53×10^{-4}
3:47	4:10	1,380	19.2	17.5	0.0139	1.14×10^{-4}
4:12	4:27	900	17.0	17.5	0.0189	1.55×10^{-4}

$$K = \frac{QL}{AHt} \qquad K = \frac{qL}{AH}$$

Remarks Average K = 1.50×10^{-4}, Mine Slurry. Test performed on reused material after compaction test.

MICHAEL BAKER, JR., INC.

Beaver, Pennsylvania

Geotechnical Engineering Department
Falling Head Permeability Test

Location Fayette Co., Pa.
Boring No. D-1-D Depth 3.5'-4.0
Sample No. 74-889
Specific Gravity, G_s 1.67
Wet Wt. of Sample 2.95 lb.
Dry Wt. of Sample W_s 1136.0 g.

Specimen Measurements
Diameter 10.16 cm
Circumference
Area, A 12.57 in^2 81.07cc^2
Length, L 11.66 cm
Volume of Sample 945.28 cc

Test No. 1
Date 10-22-74
Tested By RWD

Volume of Solid Material = $V_s = W_s/G_s$ = 680.24 cc
Void Ratio of Sample = e = $\frac{V - V_s}{V_s}$ = .3896 = ______ = ______

Dry Density = 76.9 pcf   Moisture Content = 15.1%

Test Data

Time	Elapsed Time (t) Sec.	Quantity Q cc	Area of Burette a cm^2	h_o	h_1	$\text{Log}_{10} h_o/h_1$	k cm/sec.
9:35		4.3	2.05	112.7	110.0	.0074	
10:25							
	3000						1.67×10^{-6}
10:30		5.4	1.74	109.6	106.5	.01246	
11:30							
	3600						1.98×10^{-6}
11:33		6.8	1.58	106.4	101.9	.01876	
1:05							
	5520						1.78×10^{-6}
1:08		9.2	1.70	109.6	104.2	.02194	
2:53							
	6300						1.96×10^{-6}
2:55		3.5	1.52	109.5	107.2	.00922	
3:41							
	2760						1.78×10^{-6}
3:45		5.0	1.67	106.9	103.9	.01236	
4:49							
	3840						1.78×10^{-6}
						Avg. K =	1.81×10^{-6}

$K = 2.3 \frac{aL}{At} \cdot \text{Log}_{10} \frac{ho}{h1}$ $a = \frac{Q}{h_1 - h_2}$

Remarks Material after Proctor Test was recompacted for this test.

MICHAEL BAKER, JR., INC.
Beaver, Pennsylvania

Geotechnical Engineering Department
Falling Head Permeability Test

Location Fayette Co., Pa.
Boring No. D-1-D Depth 3.5'-4.0'
Sample No. 74-889
Specific Gravity, G_s 1.67
Wet Wt. of Sample 2.99 lbs.
Dry Wt. of Sample W_s 1070.0 g.

Specimen Measurements
Diameter 10.16 cm
Circumference
Area, A 12.57 in^2 81.97 cm^2
Length, L 11.66 cm
Volume of Sample 945.28 cc

Test No. 2
Date 10-24-74
Tested By RWD

Volume of Solid Material = $V_s = W_s/G_s$ = 640.72 cc
Void Ratio of Sample = e = $\frac{V - V_s}{V_s}$ = .4753 = =

Dry Density = 74.1 pcf   Moisture Content = 21.1%

Test Data

Time	Elapsed Time (t) Sec.	Quantity Q cc	Area of Burette a cm^2	h_o	h_1	$Log_{10}h_o/h_1$	k cm/sec.
10:05		4.0	2.10	112.4	110.5	.00732	1.2 x 10^{-6}
11:15							
	4200						
11:20		4.6	1.92	110.5	108.1	.00945	.95 x 10^{-6}
1:10							
	6600						
1:13		1.95	1.95	108.0	107.0	.00389	.83 x 10^{-6}
2:03							
	3000						
2:06		1.5	1.88	106.9	106.1	.00325	.75 x 10^{-6}
2:51							
	2700						
2:54		1.7	1.89	106.1	105.2	.00368	
3:41							
	2820						.85 x 10^{-6}
3:43		1.15	1.92	105.2	104.6	.00248	
4:15							
	1920						.82 x 10^{-6}
						Avg. K =	.899 x 10^{-6}

$$K = 2.3\,\frac{aL}{At}\cdot Log_{10}\frac{ho}{h1}$$

$$a = \frac{Q}{h_1 - h_2}$$

Remarks Material after Proctor Test was recompacted for this test.

INVESTIGATION INTO THE COMBINING OF LAND RECLAMATION AT ABANDONED MINES WITH THE REMOVAL OF COAL REFUSE BANKS FOR THE PURPOSE OF GENERATING "NEW" USEFUL LAND AND THE UTILIZATION OF COAL REFUSE AS FILL

TABLE OF CONTENTS

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AREAS RECOMMENDED FOR FURTHER STUDY	X-7
THREE AREAS SELECTED FOR STUDY	X-10
RELEVANT CASE HISTORIES	X-14
CONCLUSIONS	X-24
REFERENCES	X-25

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INVESTIGATION INTO THE COMBINING OF LAND RECLAMATION AT ABANDONED MINES WITH THE REMOVAL OF COAL REFUSE BANKS FOR THE PURPOSE OF GENERATING "NEW" USEFUL LAND AND THE UTILIZATION OF COAL REFUSE AS FILL

INTRODUCTION

This task required a review of data compiled by government agencies and other sources in order to identify sites where it appears the combining of land reclamation at abandoned mines with the removal of coal waste piles is feasible, thereby generating "new" useful land and utilizing coal waste as fill. The possibility of mining the remaining coal in back of the highwall of old contour strip mines (daylighting) with placement of all or part of the overburden on land within reasonable haul distance as compacted fill for site development or similar use is also considered.

The kinds of developments for which the coal refuse and surface mine spoil is to be used for are: industrial parks; dams and access roads for recreational lakes; fill for modular unit development (trailer courts), low lying land subject to frequent flooding, areas affected by subsidence, and highways; parking areas for mass transit systems or other uses; and disposal sites for municipal, industrial solid wastes and automobile hulks.

Before this task could be accomplished it was necessary to locate the major coal mine refuse disposal areas within the Monongahela River Basin on a suitable map (Map Sheet 2 of 3). A total of 159 USGS 7-1/2 minute topographic quadrangles covering the entire basin were reviewed to determine the location of refuse disposal areas and surface mined areas. The latest available topographic maps were used and they were issued between 1953 and 1971. After this phase of the study was completed, the USGS issued photorevised maps for many areas within the basin. These recent maps show additional areas of surface mining and coal refuse disposal, but do not greatly effect the results of the study.

Although there are large coal waste disposal areas and surface mines throughout the Monongahela River Basin, they are predominantly in the western half of the basin. There is a general trend from the Greater Pittsburgh Area southward through Charleroi, California, Masontown and Point Marion in Pennsylvania; through Morgantown, Fairmont-Mannington, Clarksburg and Buckhannon in West Virginia. Most of the coal waste disposal sites are located in 12 of the 30 sub-basins designated as subdivisions by EPA in their study of the Monongahela River Basin(1). The 12 sub-basins are from north to south:

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Lower Monongahela River (Sub-Basin 1)
Lower Youghiogheny River (Sub-Basin 23)
Sewickley Creek (Sub-Basin 24)
Redstone and Dunlap Creeks (Sub-Basin 2)
Tenmile Creek, Pennsylvania - eastern area (Sub-Basin 3)
Middle Monongahela River - central area (Sub-Basin 4)
Dunkard Creek - eastern area (Sub-Basin 5)
Upper Monongahela River (Sub-Basin 6)
Buffalo and Paw Paw Creeks (Sub-Basin 7)
Lower West Fork River (Sub-Basin 8)
Elk Creek - eastern area (Sub-Basin 10)
Buckhannon River - northern part (Sub-Basin 14)

Emphasis was placed on these sub-basins when considering suitable sites for the use of coal waste and surface mine spoil, but other areas within the basin were not neglected if there appeared to be an economic incentive for development.

The ARC does not contemplate pollution abatement programs in the Monongahela River Basin simply as environmental improvement activities, but sees them as additional projects to help stimulate the lagging economy of this part of the Appalachian Region. If environmental improvements are to have beneficial effects which enhance economic prospects, they must be felt where economic activity occurs, i.e., at centers of present industrial and commercial enterprises, at those centers where opportunities for growth exist, and at locations where the quality of the natural environment is such that it is conducive to outdoor recreation. It was with these sentiments in mind that this task was performed.

In August, 1972, letters were written to responsible individuals in each of the 18 counties in the Monongahela River Basin informing them of the purpose of the task and requesting copies of their comprehensive planning reports. Many of the counties did not have this type of a report, but copies of other types of study reports were sent, some of which contained information useful for the study. Letters were also sent to the Planning and Development Division, Office of the Governor, Charlestown, West Virginia; the Department of Commerce, Harrisburg, Pennsylvania; the state highway departments of West Virginia and Pennsylvania; the U. S. Department of Agriculture, Soil Conservation Service; and other individuals who might have valuable information. The letters were followed up with telephone calls and meetings were held with several individuals having valuable input. The report "Priority Determination Procedure for the Selection of Pollution Abatement Projects in the Monongahela River Basin," prepared by Rivkin/Carson, Inc. with Arthur W. Edwards Associates(2) in March, 1972 for the ARC was also reviewed.

AREAS RECOMMENDED FOR FURTHER STUDY

The information developed during the study indicated there were many areas within the Monongahela River Basin where environmental improvement programs would also enhance the economic prospects of the area. Seventeen general locations were proposed for further investigation and over 40 types of development or activity were considered (Table 1).

Recreational Dams and Facilities

The possibility of using coal waste in the construction of multipurpose flood control, recreation and water supply dams was discussed with personnel of the U. S. Department of Agriculture, Soil Conservation Service, at Morgantown, West Virginia. It was learned they had an interest in using this material and were conducting some tests on mine waste material. Dams were planned for future construction in the following areas where coal waste was available:

1. Limestone Run near Wolf Summit, West Virginia (Sub-Basin 8)
2. Simpson Creek near Bridgeport, West Virginia (Sub-Basin 8)
3. Tenmile Creek near Lumperport, West Virginia (Sub-Basin 9)
4. Elk Creek near Elk City, West Virginia (Sub-Basin 10)
5. Sewickley Creek near Yukon, Pennsylvania (Sub-Basin 24)
6. Jacobs Creek near Scottdale, Pennsylvania (Sub-Basin 25)

Based on a review of a recreation plan(3) produced for Rices Landing Borough, Pennsylvania, a seventh recreational dam was considered. Within a radius of five miles of Rices Landing, there are at least 23 coal waste banks.

7. Pumpkin Run near Rices Landing, Pennsylvania (Sub-Basin 4)

Industrial Parks

There are many areas where industrial parks can be established. The utilization of coal waste and surface mine spoil or the backfilling of abandoned surface mines would not be a primary concern in location, even if this work was performed at no cost to the developer. More important are ready access to the site, access to a good highway network and a pleasant environment. The 11 areas presented in Table 1 were chosen for one or more of the following reasons:

1. The area is the center of present industrial and commerical activity.

2. The area is a center where opportunities for growth exist.

TABLE 1

SITES IDENTIFIED WHERE THE COMBINATION OF LAND RECLAMATION AT ABANDONED MINES WITH THE DEVELOPMENT OF "NEW" USEFUL LAND OR THE CONSTRUCTION OF FACILITIES USING COAL MINE REFUSE AND SURFACE MINE SPOIL APPEARS FEASIBLE - 1972

	Type of Development or Activity					
General Location	Recreational Dams and Facilities	Industrial Parks	Highways	Airports	Fill For Various Purposes	Daylighting
Pigeon Creek Watershed, Pa. (Sub-Basin 1)		•			•	
Uniontown-Brownsville, Pa. Area (Sub-Basin 2)		•	•		•	•
Masontown, Pa. Area (Sub-Basin 4)						•
Rices Landing, Pa. Area (Sub-Basin 4)	•	•	•		•	
Morgantown, W. Va. Area (Sub-Basin 6)		•	•	•	•	•
Limestone Run near Wolf Summit, W. Va. (Sub-Basin 8)	•					
Simpson Creek near Bridgeport, W. Va. (Sub-Basin 8)	•					•
Clarksburg, W. Va. Area (Sub-Basins 8, 10 and 11)		•	•	•	•	•
Tenmile Creek near Lumberport, W. Va. (Sub-Basin 9)	•					
Elk Creek near Elk City, W. Va. (Sub-Basin 10)	•					•
Browns Creek Watershed near Clarksburg, W. Va. (Sub-Basin 11)		•				•
Weston-Buckhannon-Elkins, W. Va. Area (Sub-Basins 11, 14, 15 and 16)		•	•	•		
Turtle Creek Watershed, Pa. (Sub-Basin 23)		•			•	
Jeannette-Greensburg, Pa. Area (Sub-Basins 23 and 24)		•			•	•
Sewickley Creek near Yukon, Pa. (Sub-Basin 24)	•	•				
Jacobs Creek near Scottdale, Pa. (Sub-Basin 25)	•	•				
Meyersdale, Pa. Area (Sub-Basin 29)		•	•			

3. The area is conducive to the development of outdoor recreational facilities. The modern trend is for industry to locate in areas where the natural environment, recreational facilities and other amenities are such that they can be considered fringe benefits in attracting and in holding employees.

4. New highways or airport expansion is planned for the area.

5. Studies have been performed which indicate the feasibility of establishing an industrial park in the area(2, 3, 4, 5, 6, 7, 8).

Highways

The review indicated major highways were planned or under construction in several areas of the Monongahela River Basin where coal waste was within hauling distance and could be made available as a construction material. The highways were:

1. Route 119 near Uniontown, Pa. (Sub-Basin 2)
2. Appalachian Corridor E near Morgantown, W. Va. (Sub-Basin 6)
3. Appalachian Corridor D west of Clarksburg, W. Va. (Sub-Basin 8)
4. Interstate 79 south of Clarksburg, W. Va. (Sub-Basin 10)
5. Appalachian Corridor H from Weston to Elkins, W. Va. (Sub-Basins 11, 14, 15 and 16)
6. Appalachian Corridor N near Meyersdale, Pa. (Sub-Basin 29)

Airports

Presently there is no gateway status airport within the boundaries of the Monongahela River Basin. The three local service commercial airports within the basin at Morgantown (Sub-Basin 6), Clarksburg (Sub-Basin 8), and Elkins (Sub-Basin 16) will be improved to "gateway" status by 1981(2). The Morgantown Airport will expand into surface and underground mined areas. The Elkins Airport does not appear promising for utilization of coal refuse, but Clarksburg Airport does.

Fill for Various Purposes

Seven areas have been recommended for utilization of coal refuse and surface mine spoil for fill for various purposes, other than industrial parks, highways, airports and recreational dams. The applicability of using this material as fill for other purposes should be investigated, but it is known that:

1. Pigeon Creek Watershed (Sub-Basin 1) and Turtle Creek Watershed (Sub-Basin 23) have areas subject to frequent flooding.

2. The U. S. Department of Housing and Urban Development has proposed a new town called Briarhill, with a population of 20,000, be built as a demonstration town between Uniontown and Brownsville (Sub-Basin 2).

3. Morgantown (Sub-Basin 6), Clarksburg (Sub-Basins 8, 10 and 11) and Rices Landing (Sub-Basin 4) have the potential for growth, and the Jeannette-Greensburg area (Sub-Basins 23 and 24) is experiencing fairly rapid growth.

4. The following urban areas in the Monongahela River Basin have mine subsidence problems(9) and coal waste and/or surface mine spoil could be used for filling surface depressions or in underground flushing projects:

   Pennsylvania: Brownsville, Charleroi, Donora and Monongahela

   West Virginia: Barrackville, Fairmont, Fairview, Farmington, Grant Town and Rivesville

Daylighting

"Daylighting," the practice of completely mining the coal in back of the highwall with placement of all or part of the overburden on land within reasonable haul distance as compacted fill for site development or similar use was recommended for further investigation in eight general areas. The recommendations were based on a review of topographic maps and most of the areas are adjacent to population centers which would benefit from a reduction in acid mine drainage and the availability of additional land for expansion. A detailed investigation would be required at each site to determine if the coal recovery "credit" is sufficient to offset the cost of reclamation to any extent. Administrative problems appear to be the major drawback in this type of operation if the property is not owned outright (surface and mineral rights) by the agency wishing to perform the project.

THREE AREAS SELECTED FOR STUDY

As part of this task, the ARC selected three areas for a more detailed study to determine if the immediate utilization of coal refuse and surface mine spoil could be encouraged. The areas selected were:

1. Morgantown Airport and surrounding area (Sub-Basin 6)
2. Appalachian Corridor "H" from Weston to Elkins, West Virginia (Sub-Basins 11, 14, 15 and 16)
3. Jacobs Creek near Yukon, Pennsylvania (Sub-Basin 25)

Morgantown Airport and Surrounding Area

The airport is located in Sub-Basin 6 (Upper Monongahela River) near the city of Morgantown, West Virginia, which is a trade, service and manufacturing center. The services include government functions as the seat of Monongalia County, West Virginia University with about 21,000 students, a Forest Services Laboratory, a Bureau of Mines Research Center and the Appalachian Laboratory for Occupational Respiratory Diseases. The 1970 census shows Morgantown with a city population of 29,431 residents, a 30.9 percent increase in population in the 1960-1970 period.

With growth of the city, transportation facilities are being expanded. Rail service originating from Morgantown is nonexistent and river travel is reserved primarily for commercial and pleasure boating. The main stem of transportation in and out of the city is by motor vehicle and airplane. Morgantown is accessible from North-South by U. S. Routes 19 and 119 and Interstate 79, and from East-West by Appalachian Corridor "E". During the study both Interstate 79 and Appalachian Corridor "E" were still under construction.

The expansion of Morgantown Airport began during World War II as a backup for the Greater Pittsburgh Airport. Since then the airport has been expanded to handle aircraft up to but not including the Boeing 747. With the growth of Pittsburgh Airport to "International" status and completion of Interstate 79, the airport will be upgraded to "gateway" status by 1981 to handle overflow traffic from the Greater Pittsburgh Airport.

Morgantown Municipal Airport is located east of the city off State Route 73 and is at an elevation of approximately 1,240 feet. There are three runways in use: 1) North-South runway approximately 3,700 feet in length, 2) East-West runway approximately 3,000 feet in length, and 3) Northeast-Southwest runway approximately 2,900 feet in length. At the present time the Northeast-Southwest runway is being extended to the southwest with a completion date of 1981. The East-West runway extension to the east is planned for completion by the year 2000.

Within a radius of 1.5 miles of the airport there are at least 17 strip mines and 69 deep mine openings; four strip mines and 11 mine openings are within the airport boundaries. Apparently there has been mining beneath the airport, but there have been no major problems of mine subsidence or settlement. There are at least 14 coal refuse banks within a radius of five miles of the airport.

The investigation of the feasibility of using mining waste for the airport expansion indicated the city of Morgantown is presently using the area of extension of the Northeast-Southwest runway for a sanitary landfill and most of the volume of material needed has already been accumulated. The sanitary landfill operation will be relocated in the area of extension of the East-West runway.

The volume of fill material required for extension of the East-West runway is 2,967,329 C. Y. and 2,543,486 C. Y. will come from cut; the balance of 423,843 C. Y. will evidently be sanitary landfill material. However, federal aid permitting funding of airport programs could accelerate the extension of this runway. In this case, coal refuse possibly could be used as borrow in the planned construction as the necessary landfill material would not be available.

Even though the utilization of coal mining waste does not appear promising for the airport extension, it could be used in site development for airport satellite industries or services, such as warehouses, light industrial developments, motels and restaurants. There are no motels in proximity of the airport.

Appalachian Corridor "H"

The highway project crosses Sub-Basins 11 (Upper West Fork River), 14 (Buckhannon River), 15 (Middle Fork River) and 16 (Upper Tygart Valley River) through the towns of Weston, Buckhannon and Elkins in West Virginia(10). The proposed alignment appears to cross some surface mines in the vicinity of Weston and coal refuse banks near Weston and north of Buckhannon should be within haulage distance.

Weston is the western terminus of the proposed Appalachian Corridor "H", a four lane extension of Interstate 66. At Weston, Corridor "H" intersects Interstate 79 and this roadway network should generate growth for the area. The city of Weston is the seat of Lewis County and it is a trade and service center located in a declining agricultural community. The production of glass products dominates its manufacturing sector. The future of Weston appears to be dependent largely on recreational services generated by the authorized construction of Stonewall Jackson Lake, a Corps of Engineers project. The 1970 census showed a population of 7,323, an increase of approximately one percent from the 1960 census. Trade and service industries should increase in response to tourist demand and a good highway network; this could develop a potential for utilization of coal refuse in site development.

Buckhannon is the seat of Upshur County and the 1970 census indicates a population of 7,261, an increase of approximately one percent since the 1960 census. West Virginia Wesleyan College has about 1,750 students and their goods and services are provided by the city. Audra State Park attracts outside visitors as well as local residents to its 355 acre recreational facilities. Although there are coal refuse banks just north of Buckhannon, the prospects of utilization do not appear to be good.

Elkins is the seat of Randolph County and the 1970 census showed a population of 3,257 residents, approximately a one percent increase over the 1960 census. It is an urban town providing trade and services for the coal and timber industries. Davis and Elkins College provides educational facilities for approximately 900 students. The coal mine refuse is not located adjacent to Elkins, but at Norton to the west. Prospects for utilization of this material do not appear to be good.

Based on information from the West Virginia Department of Highways, the proposed Appalachian Corridor "H" is in the planning stage, however, there appears to be a balance between fill and cut. The highway does not appear to be a good candidate for utilization of coal refuse or strip mine spoil at the present time, but if the alignment is shifted or if grade changes are made there is a possibility coal waste materials could be used.

Jacobs Creek

Jacobs Creek is in Sub-Basin 25 (Middle Youghiogheny River). The USDA, Soil Conservation Service, flood control and recreational project is primarily in the upstream one-third of the Jacobs Creek Watershed, east of Mount Pleasant, Pennsylvania. The project consists of one floodwater retaining structure, two multiple purpose structures and a channel improvement site. Construction contracts for the multiple purpose structure had already been let at the time of the investigation, but the floodwater retaining structure (PA-655) was in the planning and design stage. Two large coal refuse banks were within three miles of the structure and possibly could be used in construction of the embankment.

The proposed flood prevention dam is located downstream from the existing Bridgeport Reservoir Dam and would control about 30 square miles of drainage area(11). The maximum height of the proposed dam would be about 55 feet and embankment construction would require about 330,000 C.Y. of material. Mine sealing and surface reclamation in the drainage area will be required prior to construction of the facility.

The Soil Conservation Service indicated an interest in using coal refuse in construction, but did not believe this would be the best area for a demonstration project. Since this phase of the investigation, an inquiry has been received from the SCS, Morgantown, West Virginia, relative to the information developed on the engineering properties of coal mine waste. They are interested in the prospects of utilizing coal refuse in construction of flood control dams and a water supply dam for the town of Matewan in the Mate Creek Watershed, Mingo County, West Virginia. A recent telephone inquiry has indicated the project is still in the planning stage.

RELEVANT CASE HISTORIES

The following are projects performed or proposed in the last few years which illustrate the feasibility of land reclamation for the purpose of generating "new" useful land. They demonstrate the potential for: 1) turning mining wastelands into valuable real estate, 2) utilizing coal refuse for development of level land in areas where it sells for a premium, 3) surface mining methods which create relatively level land for future residential, commercial and institutional use in areas of steep terrain, 4) developing strip mines into recreational areas, and 5) daylighting mined areas to eliminate mine drainage, thereby improving the environment and land values.

Mining Wasteland Near Airport Given New Life

One of the most interesting projects involving the mining of remaining coal with placement of overburden as compacted fill for site development is taking place in Findley Township, Allegheny County, adjacent to the Monongahela River Basin (Clinton, Pa. - U.S.G.S. 7-1/2 Minute Topographic Quadrangle). An area of 4,000 acres (6.25 square miles) of thoroughly devastated land will be restored when the project is finished and it will not cost the taxpayers a cent(12).

The project is in the watershed of Potato Garden Run, a tributary of Raccoon Creek, where more than a century of mining has left mountains of coal waste and spoil, strip pits and acid streams. The mine underlying the site had been worked out years ago and deep mine entries were discharging 100,000 gallons of highly acid water a minute.

William Aloe and his brother Arthur conveived the project ten years ago. They had the foresignt to realize the area between Greater Pittsburgh Airport and U. S. Route 22 would become prime land in the near future. The 4,000 acres over the old Solar Mine was purchased from Consolidation Coal Company for $753,000, a cost of about $188/acre. Consol mined about 60 percent of the Pittsburgh coal seam at this location.

The plan calls for stripping out the remaining coal, mostly stumps and pillars. The operation involves moving millions of cubic yards of overburden, and in some areas up to 180 feet of overburden above the mine workings will be excavated. It is estimated it will take three to five years just to complete stripping operations. The recovered coal is being sold to Duquesne Light Company for its Phillips Power Station. In some areas strip pits will be utilized as sanitary landfill sites until the final grading operation is started; this will help pay the expense.

The Pennsylvania Department of Environmental Resources suggested that a seam of limestone underlying the coal be broken up so that acid water draining from the old workings would be neutralized. The limestone is also being used to pave haul roads. The idea has worked and Potato Garden Run now is running alkaline instead of acid.

State Representative John F. Laudadio said, "The state could not afford to undertake a restoration job of this magnitude. It would have cost us millions of dollars."

Mountain Top Removal and Valley Fill Reclamation

Surface mining now accounts for approximately 50 percent of all the coal produced in the United States annually. Reclamation research and new mining methods and technology to improve restoration of the land are being continually developed. Problems still exist, but steps have been taken in the direction of finding a balance between mining and the environment. In the mid-1960's a new concept of coal recovery in mountainous terrain called mountain top removal or flat top stripping was initiated. This method of surface mining creates level land where before there was none.

In the Monongahela River Basin, as well as other mountainous regions, the steep slopes and narrow valleys have left little room for farming, recreation, home, commercial and industrial development. This has crippled the economic growth of these regions. Mountain top removal is rapidly becoming one of the most effective new mining methods in mountainous regions because it provides total coal recovery and maximum protection to the environment(13). The level land remaining after mining can be used for future development. This type of total surface mining and reclamation activity requires engineering, planning and patience, but the final product generates "new" useful land.

The first large scale mountain top removal project was initiated in 1967 on property owned by Cannelton Industries, Inc. in Kanawha and Fayette Counties, West Virginia(13). In this method of mining, 100 percent of the overburden covering a coal seam or seams is removed in order to recover 100 percent of the mineral. Excess spoil is hauled to a nearby hollow to create a valley fill. A massive plateau of level, rolling land is being created by Cannelton through surface mining of three premium coal seams on a 2,000-acre tract. Overburden averages 110 feet over most of the property but ranges up to 294 feet. The high plateau at one point contains a straight stretch of 7,000 feet - long enough to handle jumbo jets if it were made into an airfield(14). By 1980, Cannelton will have surface mined 14 million tons of raw coal, whereas they could only recover 4 million tons by deep mining.

This concept of creating level land for development by removing a rugged mountain top and depositing the material in nearby hollows as a valley fill was proposed in the early 1960's by the late Dr. DeWitt Peck, a community leader in the area, but the idea never reached fruitation because of lack of funds. In 1967, Cannelton's initiation of surface mining offered the region a unique opportunity to have Dr. Peck's vision become a reality(14).

Cannelton contracted with Perry-Hylton, Inc. of Mullens, West Virginia for surface mining and reclamation of the coal reserves, but strict control over both mining and reclamation is exercised by Cannelton because the State stripping permit is issued in its name. To prevent environmental damage and to insure that there is good engineering construction, design and reclamation procedures include the following:

1. Silting basins utilizing gabion dams are installed downstream of the mining area;
2. Stabilization of valley fill material is achieved from the outset by removing all vegetation in the area of fill. This is done to prevent potential slides that could develop along a weakness caused by decayed vegetation;
3. A layer of topsoil is removed and stockpiled in a storage area;
4. An earthen dam is then constructed at the widest point of the proposed fill to establish a fill grade and prevent water runoff from the active operation;
5. Spoil deposition is limited to maximum lifts of five (5) feet so excellent compaction of material can be achieved. As filling progresses, bulldozers move constantly over the material to compact it and to retain the originally established grade;
6. The maximum finished outslope is set at 20 degrees;
7. When the fill is within established grade, 2 to 3 inches of the stored topsoil is applied to create a surface suitable for seeding;
8. Lime is disked in at the rate of three (3) tons per acre;
9. A hydroseeder sprays a mixture of water, seed and 400 pounds of fertilizer per acre and the terrain is disked for a second time to prevent seeds being blown away by the wind. Three types of grass seed are being applied. Additional stability of fill slopes is provided for by planting black locust on the outslopes and a combination of white pine, chestnut and autumn olive on the slopes' top edge.

The Community Planning Section of West Virginia Institute of Technology at Montgomery has conducted considerable feasibility studies with this plateau, east of Charleston, being created for Cannelton. The ultimate city that can be developed on this plateau could comfortably accomodate 26,000 people. Different approaches were taken in designing various cities, but in general, these cities had a commuter airport, a golf course, plenty of green area and parks, housing with large lots and beautiful scenic view above the pollution level of the valley, light industry, good schools, recreational dams and adequate and well designed transportation and utility systems. In general, different alternatives were designed for 10 people per acre. Since the communities were designed from scratch and every development was planned, West Virginia could boast a city more beautiful than Reston, Virginia or Columbia, Maryland when and if the city is built, because of its beautiful natural setting(15). One of the designs for the model city is well illustrated in an article by Blakely(15) in Coal Mining and Processing.

According to Dr. Erkan Esmer of West Virginia Tech(15), coal operators can make more money by reclaiming and developing the land and selling it, than they can by selling the coal. In this particular mining operation, reclamation costs are about $700 per acre. This amounts to $1,500,000 for the entire project. The capital improvements for building access roads, streets, utilities, parks, engineering and other incidental items, would cost about $2,000 per acre. Thus the total cost for reclaiming the land and improving it for development of a city would be about $6,000,000. If the average acre was sold for $15,000, which is a very reasonable price for a city of this type, assuming 1,300 acres of land for sale after streets and other public lands are taken off, the sale price would amount to about $20,000,000. Thus the profit would be about $14,000,000. If the average acre was sold for $20,000, then the amount of profit would be about $20,000,000.

A 53-acre plateau formed by using the mountain top removal method in McDowell County, West Virginia, near Welch was donated to the County Board of Education by Pocahontas Land Company in 1973. The gift of land, well worth over $50,000 according to local estimates, will be used as the site for construction of a new consolidated high school. The proposed $4,000,000 school would have 50 to 60 classrooms, an auditorium, a gym, a cafeteria and hopefully a planetarium. The latter would not be practical if a school was located in a valley floor. There will also be room for a baseball field and track facilities. According to School Superintendent John Drosick, "The most important thing is there is also room for some private home development. We've been lucky to hold as many teachers as we have because of the lack of living quarters. Private homes up here would be a great incentive for us to get teachers in the County." The site was strip mined by Perry-Hylton, Inc. in conjunction with Cannelton, Industries, Inc.(15)

In the Monongahela River Basin, the Kingwood Mining Company, of Preston County, is in the process of building a 450-acre hunting and fishing club near Valley Point, West Virginia. Modified mountain top removal methods are being used in strip mining. The club, to be called the Fur, Fin and Feather Club will contain ten fishing ponds(13).

At least a dozen companies in West Virginia are using this method of mining where applicable and economically feasible. Companies within the Monongahela River Basin are:

1. King Knob Coal Company, Monongalia County
2. Barbour Coal Company, Barbour County
3. Queen Brothers Coal Company, Inc., Harrison County

The mountain top removal method is also being used in the East Kentucky Coal Fields. The Martin County Coal Corporation is constructing a six mile long plateau. The Falcon Coal Company, Inc. of Hazard, Kentucky, is stripping two mountain top coal seams in Breathitt County. In this operation the overburden is being trucked to a disposal area, and Falcon officials call the method "head of hollow fill."(16) The fill is compacted as disposal progresses. It was found that the shale spoil from the rock interval between the coal seams is particularly suited for providing a surface that will support vegetation. When weathered it creates excellent soil which can be sown to grass for cattle raising or can be farmed.

The Falcon Coal Company, Inc. is also using another reclamation method known as "slope reduction." Instead of piling the spoil on the outslope of a contour pit, thereby creating an overhang that can slide or be washed down the hillside, the spoil is taken down the hillside to create a gentle slope. According to local residents, the gently sloping land is excellent for raising crops and grazing cattle. One individual is grazing 35 to 40 head of cattle in a reclaimed area. This method appears to be suitable for developing useful land where it is needed. But it should be pointed out, the Monongahela River Basin States have limitations on placing or dumping spoil on the outslope of a contour strip mine. An unstable condition such as creating an overhang on the outslope which could slide or wash down the hill would not be tolerated in the first place.

These plateaus constitute a most significant step in elevating depressed areas back to substantial economic growth and status. Establishment of brand new communities on these huge plateaus would get people off the flood prone valley floors and move them up to an altogether healthier climate or atmosphere and away from the strangulated air basins also associated with these valleys. The extraction of coal through surface mining is the only economically feasible way the region would ever secure such level land for development(13). To appreciate the significance of this concept and man's relation to his environment, one should read the excellent book by Ian McHarg, titled "Design With Nature."(17) Although this book does not delve to any extent into mined land reclamation, it does present a picture of the goals man should be striving for in designing his habitat in harmony with the environment.

New Land Utilizing Coal Refuse

In the Monongahela River Basin, near the community of Idamay in Marion County, West Virginia, 60-acres of level land were formed from a coal refuse pile for an industrial site(18). Level land in this area sells for a premium. Eight acres of the site have been occupied by a new plastics factory creating job opportunities in the area. The Idamay Mine No. 44, operated by Bethlehem Mines Corporation, developed the site with the cooperation of the local Soil Conservation Service (SCS). The land improvement effort was started six years previously when the District Conservationist for SCS drew up a conservation plan designed for a refuse pile free of pollution problems.

Starting at the base of the new refuse pile site, 150 feet of hillside was shaved off to provide some needed earthfill and to form a better anchor for the mine refuse. Bulldozers were used to spread mine refuse in 15 foot thick layers which are separated by an 18 inch soil layer. The outside part of the pile was sloped to fit the natural contour of the surrounding landscape and covered with soil. As the fill progressed upward, the outside slope was protected with a seeding of three types of grass, and mulch and fertilizer were applied with a hydromulcher. When the refuse pile reached a height of 80 feet above the base, the top surface was covered with soil and seeded. Trees were planted on the slopes. A similar operation on an older refuse pile also was carried out at Bethlehem's nearby Barrackville Mine No. 41.

The conservation plan included a desilting basin located at the base of the pile. Sludge, made up of fine refuse material, is pumped to the desilting basin from the coal preparation plant. When the basin fills completely with solid refuse, it will be covered with a layer of soil and seeded.

In Kanawha County, West Virginia, the Carbon Fuel Company is reclaiming an old refuse bank(19). The 30-acre refuse pile is still in use and its beginnings go much farther back than 1955, when Carbon Fuel started mining in the immediate vicinity. The refuse bank was graded and compacted with company owned bulldozers. Nearly 80,000 cubic yards of topsoil and clay material were deposited over the surface and spread by bulldozers. A mixture of grass seed, lime and fertilizer were spread by a hydroseeder in one operation and 1,200 lbs. per acre of fiber mulch was placed. Upon completion of the seeding operation, 300 apple trees were planted throughout the restored area.

The U. S. Bureau of Mines in a 1973 report(20) presented methods and costs for coal refuse disposal. When this work was performed by the coal operator using onsite equipment, the following cost ranges for the various phases of coal refuse reclamation were developed:

1. Transportation costs to the disposal site ranged from $0.09 to $0.28 per ton mile.

2. Spreading and compacting refuse at the disposal site ranged from $0.03 to $0.20 per ton.

3. Cost of soil cover and vegetation requirements ranged from $750 to $1,646 per acre.

The usual method of blending a refuse pile with its environment is by grading and covering with thick layers of soil, followed by vegetation with grasses, legumes and trees. According to forestry experts, approximately 18 - 24 inches of topsoil is desired for adequate growth on coal refuse piles(21). Experiments performed by the U. S. Bureau of Mines indicated comparable results can be achieved by utilizing 1.5 - 2 inches of fly ash(22, 23).

Reclamation costs per acre depend on several variables including height of the refuse bank, terrain, spoil physical and chemical parameters, acreage of area to be reclaimed, equipment used, legislative requirements and the degree of reclamation desired. With all else being equal, a cost comparison between using fly ash and bringing in soil to cover a refuse bank by Babcock(21) indicates: 1) To achieve a two foot layer of soil cover on a one refuse bank would require 4,000 tons of topsoil at a delivery and placement cost of about $1.00/ton, 2) comparable results can be achieved using fly ash for as little as $300/acre including spreading the ash, and 3) vegetation requirements and testing expenses would be virtually the same in either application.

A unique application is being employed by Valley Camp Coal Company at its Shrewsberry Mine, where fly ash from the Appalachian Power Company at its Kanawha River and Cabin Creek stations in West Virginia is blended at a ratio of 25 percent by weight with the mine refuse and transported to the disposal area by conveyor belt. Coal company officials relate that the ash fills the voids to aid in compaction, helps control spontaneous combustion and improves the pH of the material(21).

Strip Mines for Recreational Purposes

Utilization of land affected by open pit or strip mining for recreational purposes is receiving a growing interest throughout the country. The principal interest is in the reclamation and conversion of unreclaimed lands which have been mined in the past and abandoned, and the renovation of these areas into useful site for recreation activities(24).

The landscape architectural approach of developing abandoned strip mines for recreational purposes is beautifully illustrated by Miller and DeTurek in a 1968 publication(25). Their creative approach was to discover ways in which the land could be restored to accomodate the necessary needs of man and at the same time take advantage of site characteristics which in many cases possess great qualities of beauty, both man made and natural. The study selected three sites in the Anthracite Region of Pennsylvania where the needs of an expanding population could utilize the large acreages occupied by deep strip mines. To date, none of the proposed suggestions for reclamation of the strip mined areas for recreational activities have been implemented, but it has been reported the Commonwealth of Pennsylvania would be interested in a cooperative agreement if the land was purchased by others or if the land was donated to the State. The following is a summary of the landscape architectural approach recommended by the authors for reclamation of each of the three areas:

1. The Morea Strip Pits, near the two small villages of New Boston and Morea in Schuylkill County, are rural in location and adjacent to an interstate highway. Three mine voids contain many million gallons of water and during the droughts of the summers of 1965 and 1966, they provided an emergency source of water for the Pottsville area. Adjacent to the site are an airport, a golf course, an industrial park, and Locust Lake, a successful privately owned recreational center. It was recommended that because of its unique amenities, potential man-made characteristics, accessibility and location, the Morea Strip Pit area could become a widely diversified recreational area. Land areas adjacent to the bodies of water would be developed for day-use and cabin colony facilities. The Morea Pool would become the site of a flash distillation water purification plant providing the area with a potable water supply and also producing electricity. Large areas would be reforested and utilized for hiking, horseback riding, and wilderness camping. The villages of New Boston and Morea would be redeveloped as living and support facilities and the Locust Lake recreational area could be expanded providing an additional area of wide range recreational activity.

2. The Harwood-Hazleton Strip Pit, adjacent to Hazleton in southern Luzerne County, is definitely urban in nature. Hazleton is a prosperous city with a high growth potential, but disturbed and devastated mine pit areas adjacent to the boundaries of the city have controlled the pattern of surburban growth. The site is of sufficient size, scope and varying characteristics to permit a wide variety of possibilities for reclamation and development. There is an excellent highway transportation network which has made the adjacent areas become more valuable and important as land with a "future." The proposed development plan would consider the entire area as an integral part of Hazleton, but at the same time provide the necessary open space, commercial, recreational, and cultural facilities that form the heart of any urban complex. The proposed reclamation plan would include: 1) a village center with all the amenities to become the locus for the development of large areas with single and multi-family housing, 2) expansion of the existing industrial park and shopping area, 3) utilizing the voids with steep slopes as an integral part of a most challenging 36-hole PGA Golf Course, 4) a new city park in the area of water filled voids, and 5) the official agency of Mine Reclamation with a motel and visitors' center. The visitors' center would house a museum on the history of anthracite mining, geological exhibits, and will conduct tours of life experiments in mine reclamation which are in progress.

3. The Big Creek Pit is located northeast of New Philadelphia in Schuylkill County and is adjacent to Silver Creek Reservoir. It is small in size and presents a very different problem in scope from the massive Morea and Hazleton sites. A large void containing over 420 million gallons of water is the dominating characteristic. Except for the area to the immediate west and southwest, very little land area is disturbed adjacent to the pit. This strip pit has the potential for becoming the prime example of successful reclamation through complete analysis and use of existing man-made characteristics. The natural access becomes the main entrance to a lodge facility complete with restaurant, recreational facilities, and overnight accomodations. The lodge, the locus of a state park, is located on the edge of the void which becomes a lake for boating, sailing, and other water sports. Adjacent facilities for swimming, tennis and horseback riding make the lodge a complete recreation center.

In 1973, the Bureau of Outdoor Recreation (BOR) of the Department of the Interior organized the first National Conference on the Reclamation of Surface Mined Lands for Outdoor Recreation(26) and conferences were held in each of seven regions. Major recommendations of the National Conference were that State governments should be the focal point of a comprehensive inventory of surface mined land; that the BOR should coordinate and disseminate data on sources of technical and financial assistance available to public and private reclamation interests; that the mining industry should play a key role in reclamation by planning for recreational reclamation on active and proposed mine sites; and that regional land reclamation committies, composed of experts from public and private organizations should be created to advise the BOR.

A joint Bureau of Mines - Bureau of Outdoor Recreation reconnaissance evaluation of potential surface mined sites for outdoor recreation led to one coal strip mine in the Monongahela River Basin being approved as a demonstration project(27). An abandoned strip mine in the Pendleton Run Area of Tucker County, West Virginia, about 50 miles east of Clarksburg will be developed for off-road recreation vehicles and shooting sports.

Daylighting Mined Areas

Daylighting is a term used to define the surface mining procedure for exposing an entire underground mined area to remove all the remaining mineral underlying the surface(28). A form of daylighting has been practiced for years in the Anthracite Region of Pennsylvania where steeply pitching coal seams of old deep mined workings have been surface mined to an economic depth to win the remaining coal near the surface and pillars at depth. The methods discussed in Section II of this report under "The Concurrent Reclamation of Partially Worked Out Deep and/or Surface Mines and the Recovery of Coal Reserves" can be considered as partial daylighting. In the same section, the example of what could be accomplished in the Browns Creek Watershed near Clarksburg, West Virginia, if environmental, mineral resource, economic, land use and political factors are considered would be daylighting. In this section, the case history of what is being accomplished by the Aloe Brothers in the watershed of Potato Garden Run, Allegheny County, Pennsylvania, is also daylighting.

It appears daylighting of old mine workings has been practiced by surface mine coal operators since at least the World War II period. In many cases, only part of the hill had been deep mined, but surface mining removed all the coal including what remained in the deep mined area. This was particularly true in parts of north central and southwest Pennsylvania where the overburden thickness was within a range of economic feasibility.

Daylighting for the purpose of abating acid mine drainage from old contour strip mines and abandoned deep mines with placement of overburden on land within reasonable haul distance as compacted fill for site development or similar use has to be considered in a different light. The coal recovery credit in most cases will only partially offset the cost of the reclamation project. If it is possible to win the coal at a profit or if the profit potential for developing new land is great enough, the coal industry or others will perform the operation. This leaves most of the marginal or unprofitable reclamation projects to governmental agencies. Although, there appears to be an economic potential for government in the very large projects, those which industry does not have the capital or organizing abilities to perform. An example of this type would be a Browns Creek Watershed project where long range planning is required; the initial capital and operating costs would be very high; there are a great number of property owners, both surface and mineral, and profit would be nonexistant for a long period of time.

The difficulties of a government agency daylighting a combination surface and deep mining complex are well exemplified by the Deer Park Daylighting Demonstration Project in Garrett County, Maryland(29). The actual daylighting has been forestalled because of difficulties in acquiring legal property rights, easements and methods of awarding contracts. The project site is a 70 acre area in the upper Potomac River Basin and it is essentially a single hill. At least six deep mine operators have worked in the area and four strip mine operators have stripped around the hill. It is estimated daylighting should eliminate 500 lbs. of acid per day draining into the North Branch of the Potomac River by way of Lostland Run.

In September, 1973, the estimated costs for project completion were as follows:

Estimated Construction Cost	$476,760
Credit for Coal Sale	-191,000
*Credit for Required Reclamation	- 4,500
Estimated Net Cost	$281,260
Water Analysis	6,450
Soil Nutrient Analysis	3,800
Engineering plus Fee (Including stream gauging stations and sediment monitoring stations)	191,225
Total	$482,735

*Based on a $300/acre cost of reclaiming 15 acres of unreclaimed strip mine.

The estimated cost of the demonstration project does not include State of Maryland salaries and expenses. The estimate was made before the recent surge in coal prices which should adjust the coal credit upward making the feasibility of daylighting more attractive. It should be pointed out that this is a demonstration project and the engineering and associated costs, such as stream gauging, sediment monitoring stations, water analysis and other costs probably would be much lower for a normal reclamation project.

CONCLUSIONS

The investigation performed as part of this task and the case histories presented indicate there are several approaches to reclaiming abandoned and active mining sites for "new" useful land. These viable approaches should be encouraged. Daylighting of abandoned mines has many problems which have to be resolved before this method can be considered in the range of economic feasibility. These problems are mostly administrative, and perhaps the proposed federal "Surface Mine Control and Reclamation Act of 1975," under Title IV - Abandoned Mine Reclamation(30), will be instrumental in resolving some of the problems.

Pollution abatement projects in the Monongahela River Basin should not be considered just simply as environmental improvement activities, but as additional projects to help stimulate the lagging economy of this part of the Appalachian Region, i.e., the projects should enhance the economic prospects of the area.

The prospects of reclaiming and conservation of valuable lands through the utilization of coal refuse as a construction material has been discussed in several recent publications by Doyle and Chen(31), Maneval and Montgomery(32), Maneval(33, 34), and Business Week(35).

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MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
1	1	2(1960)	40°25'00" 79°55'00"		69			
2	23	3(1960-69)	40°27'30" 79°47'30"		183			
3	23	3(1960-69)	40°22'35" 79°52'00"		23			
4	23	4(1953)	40°29'55" 79°44'40"	Consolidated Renton	101	6,000		No water impounded by bank, but 2 slurry ponds are adjacent to bank, 1 holds water. Partially burning. 2000 x 1600 x 80 **Outside of Basin
5	23	4(1953)	40°28'45" 79°44'55"		5			
6	23	5(1954)	40°24'45" 79°37'10"		62			

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PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
7	23	5(1954)	40°25'10" 79°37'08"		20			
8	23	5(1954)	40°25'05" 79°35'55"		34			
9	23	5(1954)	40°27'33" 79°30'55"		71			**Outside of Basin
10	1	6(1960-69)	40°16'50" 80°00'54"	Consolidated Coal Co. Montour #10	34			
11	1	6(1960-69)	40°21'20" 80°01'30"		20			**Outside of Basin
12	1	6(1960-69)	40°19'20" 80°02'35"		24			**Outside of Basin

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Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
13	1	6(1960-69)	40°21'35" 80°04'00"		18			**Outside of Basin
14	1	6(1960-69)	40°18'20" 80°07'05"	Consolidated Montour #4	42	2,749		Abandoned. Max. Slope angle 70-80° where encountered. 1200 x 400 x 80. Impoundment 600 x 150 x 40 **Outside of Basin
15	1	6(1960-69)	40°17'45" 80°07'05"	Consolidated Montour #4	46	3,702		Abandoned. Max. slope angle = 50°. Burned out. 1500 x 350 x 100 Impoundment is 800 x 150 x 2 **Outside of Basin
16	1	7(1960-69)	40°20'30" 79°56'50"		251			**Field check revealed that this is not a refuse dump, but is a furnace slag dump.
17	1	7(1960-69)	40°21'25" 79°55'10"		14			
18	1	7(1960-69)	40°18'00" 79°53'25"		33			

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PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
19	23	8(1960)	40°19'50" 79°50'08"	Tower Hill #1	15			
20	23	9(1953-69)	40°22'15" 79°38'00"		40	4,889		Abandoned. Max. slope angle = 40° 1500 x 800 x 150
21	24	9(1953-69)	40°18'00" 79°39'00"	Edna #1	9			
22	24	9(1953-69)	40°16'00" 79°40'30"		18			
23	24	9(1953-69)	40°15'45" 79°40'45"		4			
24	24	9(1953-69)	40°17'45" 79°41'15"	Edna #2	10	1,629		Abandoned. Max. Slope angle = 40° 2800 x 1000 x 200

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PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
25	24	9(1953-69)	40°17'00" 79°41'45"		6	726		Abandoned. Max. Slope angle = 40° 800 x 400 x 150
26	24	9(1953-69)	40°15'45" 79°42'15"		7	356		Abandoned. Max. Slope angle = 35° Slide potential. 500 x 300 x 60
27	24	9(1953-69)	40°15'45" 79°42'25"		16	1,889		Abandoned. 1000 x 500 x 150
28	24	9(1953-69)	40°16'00" 79°42'30"		11	710		Abandoned. Max. Slope angle = 70-80° where excavated. 1200 x 400 x 80 Impoundment 600 x 150 x 40
29	24	9(1953-69)	40°17'45" 79°43'15"		20			
30	23	10(1954-69)	40°22'15" 79°37'15"		10	652		Abandoned. 2000 x 1200 x 80

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Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
31	23	10(1954-69)	40°20'15'' 79°31'20''		2			**Outside of Basin.
32	5	10(1954-69)	40°20'50'' 79°31'15''		5	700		**Outside of Basin.
33	5	12(1953-69)	40°12'16'' 80°14'35''		9			**Outside of Basin.
34	5	12(1953-69)	40°14'10'' 80°12'10''		39			**Outside of Basin.
35	5	12(1953-69)	40°13'25'' 80°12'40''		16			**Outside of Basin.
36	5	12(1953-69)	40°13'20'' 80°12'30''		6			**Outside of Basin.

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Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons).	Remarks
37	5	12(1953-69)	40°11'30" 80°13'15"		11			**Outside of Basin
38	1	13(1953-69)	40°08'00" 80°03'00"	Jones & Laughlin Somerset #60	13			4 settling ponds, water not impounded by refuse bank, water recycled. 25' wide, 50' high w/7' freeboard. Impoundment present is 700 x 500 (largest pond)
39	1	13(1953-69)	40°11'10" 80°01'15"		6			
40	1	14(1954)	40°07'50" 79°59'55"	Gibson Mine	10			
41	1	14(1954)	40°08'10" 79°59'24"	Gibson Mine	7			
42	1	14(1954)	40°12'04" 80°00'00"	U.S. Steel Maple Creek #1 & 2	140	2,259		Pond banks made w/20' clay core. 40 acres. Dump is 130-140 acres x 100' high.

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Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
43	1	14(1954)	40°09'10" 79°58'40"		3	67		Abandoned. Slide potential. 1600 x 500 x 30
44	1	14(1954)	40°09'40" 79°58'28"		4			
45	1	14(1954)	40°12'45" 79°58'50"	U.S. Steel Corp. Mathies Mine	17			
46	1	14(1954)	40°12'30" 79°58'30"	Consolidated Coal Co. Mathies Mine	32			Burning pile. 170' wide x 150' high. Settling pond, partially filled with fines. Drainage thru seepage. Pond is 40 acres.
47	1	14(1954)	40°12'10" 79°58'00"	U.S. Steel Corp. Mathies Mine	13			
48	1	14(1954)	40°10'25" 79°57'25"		13			

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Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
49	1	14(1954)	40°10'25" 79°56'52"		8			
50	1	14(1954)	40°08'36" 79°54'45"		8			
51	1	14(1954)	40°08'50" 79°54'12"		9			
52	1	14(1954)	40°09'00" 79°54'30"		7			
53	1	14(1954)	40°10'00" 79°54'02"		7	474		Abandoned. Max. Slope angle = 45° Slide potential. 1000 x 300 x 80
54	1	14(1954)	40°08'20" 79°53'15"		5	711		Abandoned. Max. Slope angle = 45° Slide Potential. 600 x 400 x 160

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Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
55	1	15(1954-69)	40°13'00" 79°52'15"		14	778		Abandoned. Max. Slope angle - 40° 700 x 900 x 70
56	1	15(1954-69)	40°11'15" 79°52'15"		4	444		Abandoned. Max. Slope angle = 40° 2000 x 1200 x 150
57	1	15(1954-69)	40°08'30" 79°51'00"		14	1,007		Abandoned. Max. Slope Angle = 50° 1500 x 1000 x 80
58	1	15(1954-69)	40°09'15" 79°50'00"		10			
59	23	15(1954-69)	40°13'30" 79°48'00"		10			
60	23	15(1954-69)	40°13'15" 79°47'45"		8			

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PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
61	23	15(1954-69)	40°11'45" 79°45'55"	Republic Steel Corp. Banning #4	13			
62	23	15(1954-69)	40°11'40" 79°45'50"	Republic Steel Corp. Banning #4	18			
63	23	15(1954-69)	40°11'50" 79°45'50"	Republic Steel Corp. Banning #4	1			
64	23	15(1954-69)	40°11'45" 79°45'45"	Republic Steel Corp. Banning #4	2			
65	23	15(1954-69)	40°10'30" 79°45'30"	Republic Steel Corp. Banning #4	7	592		Abandoned. Slide Potential 900 x 500 x 100
66	25	15(1954-69)	40°07'30" 79°45'00"		14			

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Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
67	24	16(1954)	40°08'30" 79°44'45"		28			
68	24	16(1954)	40°13'20" 79°43'50"	Pittsburgh Coal Co. Div. Consol. Coal Co. Hutchinson Mine	25	1,600		2200 x 1100 x 80' Burning. Impoundment 2200 x 300 x 15. Abandoned.
69	24	16(1954)	40°09'10" 79°43'24"	Sager Mine	10	571		Abandoned. Slide Potential. 1400 x 500 x 70
70	24	16(1954)	40°13'30" 79°41'10"	Magee Mine	5	556		Abandoned. 1700 x 1700 x 150
71	24	16(1954)	40°13'20" 79°41'05"	Magee Mine	3			
72	24	16(1954)	40°13'15" 79°41'00"	Magee Mine	1			

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PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
73	24	16(1954)	40°13'08" 79°40'54"	Magee Mine	1			
74	24	16(1954)	40°11'30" 79°42'10"	Youghiogheny-Ohio Coal Company Wyano Mine	44	2,800		Sold to Mr. & Mrs. Hays. **Inactive.** Partially burned.
75	24	16(1954)	40°12'25" 79°38'50"	Eastern Assoc. Coal Company Delmont Mine	9	592		Abandoned 1800 x 400 x 80 Max. Slope angle = 40°
76	24	16(1954)	40°12'20" 79°38'25"	Eastern Assoc. Coal Company Delmont Mine	22	1,422		1500 x 700 x 80 Impoundment is 900 x 300
77	24	17(1964)	40°12'04" 79°37'28"		3			
78	24	17(1964)	40°12'12" 79°37'25"		2			

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PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
79	24	17(1964)	40°12'18" 79°37'18"		3			
80	24	17(1964)	40°12'25" 79°37'05"		6			
81	25	17(1964)	40°09'38" 79°32'00"	Standard Coal Co. Standard Mine	6	871		Sold to a Mr. Mullens. Inactive. Height 200 feet. Patially burned.
82	25	17(1964)	40°00'05" 79°30'10"	Standard Mine	7			
83	24	18(1967)	40°12'40" 79°28'50"		7			
84	24	18(1967)	40°12'15" 79°28'30"	Clinchfield Coal Co. Div. Pittsburgh Coal Company Compass #2 & 3	5	667		Dump is 1500 x 1500 x 150. Three adjacent slurry ponds 1500 x 1000

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Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
85	24	18(1967)	40°14'50" 79°26'45"		9	815		
86	1	23(1954)	40°05'48" 80°05'05"	Buckeye Coal Co. Ontario Mine	23	2,963		Burning. North slope shows evidence of sliding. 1700 x 600 x 100
87	1	23(1954)	40°05'55" 80°04'50"	Buckeye Coal Co. Ontario Mine	6			Burning. 700 x 500 x 60
88	1	23(1954)	40°05'55" 80°04'38"	Bethlehem Mine Co. Cokeburg Mine	29	2,000		
89	1	23(1954)	40°05'40" 80°04'15"	Bethlehem Mine Co. Cokeburg Mine	9			Primarily slurry pond w/7' freeboard & spillway. Impoundment present is 200 x 200
90	3	23(1954)	40°00'54" 80°06'35"	Bethlehem Mine Co. Mariana #58	28	1,837		100 x 400 x 80

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PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
91	3	23(1954)	40°01'15" 80°06'25"	Bethlehem Mine Co. Mariana #58	42	2,725		Burning. 1500 x 600 x 80
92	3	23(1954)	40°01'30" 80°06'10"	Bethlehem Mine Co. Mariana #58	9	872		1000 x 400 x 80
93	3	23(1954)	40°00'45" 80°05'50"	Bethlehem Mine Co. Mariana #58	19			
94	1	23(1954)	40°06'52" 80°01'53"	Bethlehem Mine Co. Ellsworth #51	7			
95	1	23(1954)	40°07'08" 80°01'45"	Bethlehem Mine Co. Ellsworth #51	26			
96	1	23(1954)	40°07'00" 80°01'30"	Bethlehem Mine Co. Ellsworth #51	44	3,554		Slurry pond, not impounded by dump Pond 2000 x 75 x 12 Dump 1000 x 800 x 100.

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
97	1	23(1954)	40°06'30" 80°01'25"	Bethlehem Mine Co. Ellsworth #51	4	178		Burnt. 800 x 80 x 60.
98	1	23(1954)	40°06'20" 80°01'20"	Bethlehem Mine Co. Ellsworth #51	9	871		Burning. 900 x 700 x 120
99	1	23(1954)	40°06'40" 80°01'07"	Bethelehem Mine Co. Ellsworth #51	7			
100	1	23(1954)	40°06'52" 80°01'07"	Bethlehem Mine Co. Ellsworth #51	6			
101	3	23(1954)	40°03'15" 80°01'35"	Jones & Laughlin Vesta #4	38	4,038		Burning. 1400 x 1200 x 140
102	3	23(1954)	40°00'00" 80°02'15"	Republic Steel Clyde Mine	3			Pond constructed on old pile. 1600 x 1500 x 60. Impoundment present is 1000 x 700

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
103	4	24(1954-69)	40°01'15" 79°59'30"	J. & L. Steel Corp. Vesta #5	30	2,833		Abandoned. 2100 x 1400 x 120
104	4	24(1954-69)	40°00'35" 79°58'50"		11			
105	4	24(1954-69)	40°00'40" 79°58'45"		4			
106	4	24(1954-69)	40°00'40" 79°58'40"	U.S. Steel Corp. Maxwell Mine	10	978		Burning. 2600 x 800 x 120
107	4	24(1954-69)	40°00'00" 79°58'45"	J. & L. Steel Corp. Vesta #5	315	45,733		Slurry pond, 1/2 full of sludge. 5000 x 3000 x 180. Partially burned.
108	1	24(1954-69)	40°05'30" 79°57'52"		6	267		Burning. 1000 x 200 x 60

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
109	1	24(1954-69)	40°05'10" 79°57'50"	Maria Bros. Mine Co.	6	259		Burning. 3000 x 2000 x 50
110	1	24(1954-69)	40°04'22" 79°57'45"		4	178		300 x 500 x 60
111	1	24(1954-69)	40°03'15" 79°56'52"	Consol. Coal Co. Crescent Mine	4	444		600 x 400 x 150
112	1	24(1954-69)	40°06'30" 79°55'30"		17			
113	1	24(1954-69)	40°05'22" 79°55'15"		8	666		Burning. 2400 x 600 x 100
114	1	24(1954-69)	40°04'00" 79°55'15"		8	533		1000 x 300 x 80

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
115	1	24(1954-69)	40°04'10" 79°54'55"		6			
116	1	24(1954-69)	40°04'00" 79°54'55"		6	267		500 x 150 x 60
117	1	24(1954-69)	40°03'53" 79°54'25"	Baker Bros. Mine Company	5	370		800 x 300 x 100
118	1	24(1954-69)	40°03'50" 79°54'15"	Baker Bros. Mine Company	6	222		1000 x 300 x 50
119	4	24(1954-69)	40°00'25" 79°56'25"	J. & L. Steel Corp. Vesta #7	14	5,556		Burning pile 1200 x 1000 x 140. Impoundment present is 300 x 80 x 3
120	4	24(1954-69)	40°00'15" 79°56'07"	J. & L. Steel Corp. Vesta #6	4	356		Burning. 800 x 500 x 120'

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
121	2	24(1954-69)	40°00'28" 79°53'20"		2	74		Bank is 700 x 200 x 50
122	2	24(1954-69)	40°00'00" 79°53'20"		20			Bank is 1400 x 300 x 50
123	1	25(1954)	40°06'15" 79°51'00"		5			
124	2	25(1954)	40°01'40" 79°51'45"		13			
125	2	25(1954)	40°01'30" 79°51'12"		6			
126	2	25(1954)	40°01'15" 79°50'00"		6			

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
127	2	25(1954)	40°00'45" 79°48'00"		12			
128	2	25(1954)	40°00'15" 79°47'30"		6	311		Abandoned. Max. Slope angle = 40° 1200 x 400 x 60
129	1	25(1954)	40°03'45" 79°47'35"		14			
130	25	25(1954)	40°03'30" 79°46'40"		28			
131	25	26(1964)	40°01'43" 79°40'00"		253			
132	26	28(1967)	40°01'15" 79°24'30"	Indianhead Mine	7			

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
133	26	28(1967)	40°03'45" 79°23'00"	Melcroft Mine	26	622		Abandoned. 600 x 400 x 30
134	3	36(1961)	39°55'45" 80°03'20"	Pickands & Mather Mather Mine	40	6,518		Spoil bank burning. 2 acre rain pond. 2600 x 800 x 200
135	3	36(1961)	39°57'50" 80°02'50"	Hillman Coal & Coke Company Edwards Shaft	35	562		Burning bank. 1900 x 1200 x 20
136	3	36(1961)	39°58'40" 80°02'05"	Hillman Coal Co. Hillman Mine	18	740		Burning. Excavated to 70° slope. 500 x 400 x 50
137	3	36(1961	39°58'53" 80°02'05"		2			
138	3	36(1961)	39°58'53" 80°01'30"		6			

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
139	3	36(1961)	39°54'20" 80°01'07"	Hillman Coal & Coke Company Emerald Mine	17	666		1200 x 600 x 50
140	3	36(1961)	39°59'40" 80°00'45"	Republic Steel Corp. Clyde Mine	23	1,296		2000 x 900 x 70
141	4	36(1961)	39°59'40" 80°00'00"	Republic Steel Corp. Clyde Mine	24	2,889		Inactive, 4000 x 1200 x 150. Inactive 25 acre slurry pond also present.
142	4	36(1961)	39°57'45" 80°00'15"		9			
143	4	37(1964)	39°59'45" 79°59'45"	Republic Steel Corp. Clyde Mine	22	3,207		1000 x 1400 x 70
144	4	37(1964)	39°57'10" 79°58'08"	National Mine Corp. Crucible Mine	6	311		Two banks. 1200 x 300 x 60, 2000 x 300 x 60. Small pond.

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
145	4	37(1964)	39°55'38" 79°59'00"	Crucible Steel Corp. Cumberland Twp. Mine	13	883		Burning. Vertical slope. 1000 x 00 x 80
146	4	37(1964)	39°57'40" 79°57'55"	National Mines Corp. Crucible Mine	[illegible]	3,852		Two ponds. Bank burning. 1800 x 1500 x 260.
147	4	37(1964)	39°56'30" 79°56'00"	National Mines Corp. Isabella Mine	59	6,636		3 slurry ponds, 3' deep, 3', 6', 15' freeboards respectively. Diversion ditch & overflow provided. Burning 2400 x 1600 x 140.
148	4	37(1964)	39°53'10" 79°55'30"	Buckeye Coal Co. Nemacolon Mine	39	7,644		2 slurry ponds: Upper, 4 acres w/50' freeboard. Lower, 10 acres w/7' freeboard. 2700 x 3000 x 240
149	4	37(1964)	39°54'45" 79°55'10"		8	800		Burning bank. 1700 x 900 x 120
150	4	37(1964)	39°53'30" 79°55'15"		6			

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
151	4	37(1964)	39°55'15" 79°53'25"		20	2,078		Two banks, both burning. North 1400 x 400 x 120 South 1500 x 500 x 60
152	4	37(1964)	39°53'15" 79°53'25"		9	148		Bank is 1600 x 600 x 200
153	2	37(1964)	39°57'30" 79°53'45"	Thompson #2	7			
154	2	37(1964)	39°56'30" 79°53'40"	Thompson #1	6			
155	2	37(1964)	39°57'40" 79°52'30"		10	652		Bank is 700 x 400 x 80
156	2	37(1964)	39°56'40" 79°52'30"	Republic Steel Corp. Tower Hill #1	6			

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
157	4	37(1964)	39°54'10" 79°52'30"		16			
158	2	38(1964)	39°56'55" 79°51'20"	Orient Mine	16	1,511		Abandoned. Potential slide area. 1200 x 400 x 120
159	2	38(1964)	39°58'55" 79°52'20"		6	667		Being reclaimed. 700 x 200 x 150
160	2	38(1964)	39°55'50" 79°50'45'		8			
161	2	38(1964)	39°55'40" 79°50'30"		9			
162	2	38(1964)	39°56'20" 79°49'50"		15	592		Abandoned. Slide potential. 1800 x 400 x 50

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
163	2	38(1964)	39°56'25" 79°49'50"	Herbert Mine	4	148		Abandoned. 500 x 400 x 50
164	2	38(1964)	39°56'50" 79°49'00"	Searsights Mine	11			
165	2	38(1964)	39°56'45" 79°48'45"	Searsights Mine	17			
166	2	38(1964)	39°56'15" 79°48'15"	Dearth Mine	33			
167	2	38(1964)	39°56'20" 79°48'15"	Dearth Mine	5	200		
168	2	38(1964)	39°59'00" 79°48'15"	Chestnut Ridge Mine	15			

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
169	2	38(1964)	39°58'00" 79°47'00"	Helen Mine	29			
170	2	38(1964)	39°59'30" 79°46'55"		1			
171	2	38(1964)	39°53'35" 79°46'20"	Clayford Mine	8			
172	2	39(1963)	39°59'38" 79°41'20"	Juniata Mine	7			
173	2	39(1963)	39°56'45" 79°38'30"		5	185		Abandoned three banks. 1400 x 400 x 50 (largest)
174	27	39(1963)	39°59'45' 79°38'30"		6	267		Abandoned. Slide potential. 1000 x 300 x 60

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
175	27	39(1963)	39°59'50" 79°39'00"		2	94		Abandoned 500 x 300 x 100
176	29	45(1967)	39°54'45" 79°58'25"		6			
177	4	50(1964)	39°49'45" 79°58'45"		44			
178	4	50(1964)	39°49'40" 79°57'00"	U.S. Steel Corp. Robena Slope Mine	70	5,627		Max. Slope angle = 35° 6600 x 6100 x 100 9.3 Acre impoundment
179	5	50(1964)	39°46'07" 79°58'00"		2			
180	5	50(1964)	39°45'55" 79°57'55"		2			

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
181	5	50(1964)	39°45'50" 79°57'35"		25			
182	5	50(1964)	39°45'10" 79°58'30"		5	148		Abandoned. 1500 x 900 x 40
183	5	50(1964)	39°45'00" 79°58'40"		6			
184	5	50(1964)	39°46'10" 79°56'35"	Dunkard Mining Co. Poland Mines	26			
185	6	50(1964)	39°45'10" 79°55'40"	Dilliner Mine	5			
186	5	50(1964)	39°47'05" 79°56'20"	Dunkard Mining Co. Poland Mines	14	555		Abandoned. 800 x 700 x 50

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
187	4	50(1964)	39°48'30" 79°55'25"		29			
188	4	50(1964)	39°49'20" 79°55'35"		[illegible]			
189	4	50(1964)	39°49'50" 79°51'07"		124			
190	4	50(1964)	39°50'10" 79°56'26"		9			
191	4	50(1964)	39°50'25" 79°56'22"		5			
192	4	50(1964)	39°50'15" 79°56'15"		9			

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
193	4	50(1964)	39°49'35" 79°55'05"		3			
194	4	50(1964)	39°50'10" 79°54'50"		6	311		Abandoned. Max. Slope angle = 38° 800 x 500 x 60
195	4	50(1964)	39°50'35" 79°53'10"		9			
196	6	62(1958)	39°39'45" 80°04'25"	Consol. Coal Co. Osage #36	21	600		
197	6	62(1958)	39°40'15" 80°03'15"	H.R. Headlee Private Owner	11	176		Bank 1800 x 200 x 20 Pond 100 x 50 x 8 *Originally Consol. Coal Co., Bunker Mine
198	6	62(1958)	39°40'47" 80°01'00"		6			

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
199	6	62(1958)	39°40'45" 80°00'50"		5			
200	6	62(1958)	39°40'00" 80°00'20"		6			
201	6	62(1958)	39°39'10" 80°00'40"		16			
202	6	62(1958)	39°39'05" 80°00'00"	Consol. Coal Co. Awkwright #16	25			
203	6	62(1958)	39°38'45" 80°00'00"	Consol. Coal Co. Awkwright #16	23	1,851		Bank 2,000 x 200 x 100 Pond is 1/2 acre
204	6	63(1957)	39°40'10" 79°59'50"	Christopher Coal Co. Div. Consol. Coal Co. Humphrey #7	51	2,444		Bank compacted and layered with clay. 3600 x 800 x 60. Pond is 3 acres.

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
205	6	63(1957)	39°41'25" 79°59'20"	Petitte Mining Co. Petitte #1	21	511		Burning 1800 x 300 x 30 Pond is 2 acres.
206	6	63(1957)	39°43'08" 79°58'08"		6			
207	6	63(1957)	39°43'08" 79°57'20"		6			
208	6	63(1957)	39°44'45" 79°55'50"		4			
209	18	63(1957)	39°44'55" 79°52'55"		6			
210	18	63(1957)	39°41'10" 79°53'30"		9			

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
211	18	63(1957)	39°40'30" 79°33'45"		4			
212	18	63(1957)	39°40'20" 79°54'02"		4			
213	7	73(1960)	39°32'00" 80°18'05"		7			
214	7	73(1960)	39°32'00" 80°17'55"		6			
215	7	73(1960)	39°31'00" 80°18'00"	Eastern Assoc. Coal Co. Joanne Mine	27	1,299		There are 6 impoundments. Bank is separate. 2000 x 700 x 60.
216	7	73(1960)	39°30'08" 80°15'00"	Mountaineer Coal Co. Div. of Consol. Coal Co. Consol #9	42			

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
217	7	74(1960)	39°32'15" 80°14'50"	Consol. Coal Co.	22			
218	7	74(1960)	39°30'15" 80°14'00"	Consol. Coal Co.	6	300		
219	7	74(1960)	39°30'15" 80°10'30"	Bethlehem Steel Corp. #41	57	2,756		Compacted and covered with clay. 1200 x 1200 x 60. Impoundment 250 x 1000 x 15
220	7	74(1960)	39°33'45" 80°10'00"	Eastern Assoc. Coal Co. Federal #1	102	8,219		Burning. Compacted slag and clay: 3/4 of impoundment is slag: 20% moisture. 5000 x 3000 x 100. Impoundment is 1500 x 400 x 15
221	6	75(1960)	39°32'00" 80°07'00"	Montana Mines	2			
222	6	75(1960)	39°32'05" 80°06'40"	Montana Mines	6			

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
223	6	75(1960)	39°32'00" 80°06'10"	Montana Mines	2			
224	6	75(1960)	39°32'45" 80°05'15"	Mountaineer Coal Co. Div. of Consol. Coal Co. #93	39			
225	6	75(1960)	39°33'30" 80°04'02"		3			
226	6	75(1960)	39°34'10" 80°03'20"		6			
227	6	75(1960)	39°35'08" 80°02'30"	National Coal Co. Christopher #56	2			
228	6	75(1960)	39°35'10" 80°02'05"	National Coal Co. Christopher #56	3			

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
229	6	75(1960)	39°37'00" 80°01'10"		5			
230	6	75(1960)	39°37'10" 80°01'17"	Christopher Mines	3			
231	6	76(1957)	39°31'30" 79°58'45"	Wierton Mines	13			
232	6	76(1957)	39°32'15" 79°58'40"	Wierton Mines	6			
233	6	77(1960)	39°32'38" 79°49'22"		11			
234	6	77(1960)	39°32'38" 79°48'30"		11			

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
235	6	77(1960)	39°33'15" 79°48'25"		9			
236	6	78(1959)	39°30'10" 79°44'30"		10			
237	18	79(1959)	39°34'57" 79°36'15"		7			
238	8	85(1960)	39°25'15" 80°18'00"	Mountaineer Coal Co. Div. Consol. Coal Co. Williams Mine	102	3,286		Dump is 450 x 100 x 40. Pond is 1500 x 450 x 10.
239	8	85(1960)	39°28'15" 80°18'00"	Mountaineer Coal Co. Div. Consol. Coal Co. Consol #20	22	2,667		Dump is 100 x 400 x 150. Impoundment 1000 x 300 x 25
240	8	85(1960)	39°22'30" 80°15'00"	Consol. Coal Co. Owings Mine #1	32	3,000		

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
241	8	86(1958)	39°27'15" 80°13'45"		35			
242	8	86(1958)	39°24'55" 80°12'30"		6			
243	20	91(1959)	39°29'10" 79°31'20"		9			
244	9	96(1960)	39°22'30" 80°26'15"	Clinchfield Coal Co. Div. Pittston Coal Co. Compass #2 & 3	23	1,400		
245	9	97(1958)	39°22'30" 80°19'55"		5			
246	8	97(1958)	39°21'15" 80°18'15"	E & S Coal Co. #5	9			

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
247	8	97(1958)	39°21'15" 80°18'00"	E & S Coal Co. #5	77			
248	8	97(1958)	39°20'46" 80°17'20"		3			
249	8	97(1958)	39°19'10" 80°17'45"		4			
250	8	97(1958)	39°17'55" 80°20'16"		0.5			
251	8	97(1958)	39°17'55" 80°20'10"		0.5			
252	8	97(1958)	39°17'55" 80°20'07"		0.5			

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
253	8	98(1960)	39°21'15" 80°14'45"		7			
254	8	98(1960)	39°20'54" 80°14'38"		8			
255	8	98(1960)	39°20'54" 80°14'30"		7			
256	8	98(1960)	39°20'46" 80°14'12"		6			
257	8	98(1960)	39°20'54" 80°13'54"		13			
258	8	98(1960)	39°18'20" 80°08'40"		9			

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
259	12	98(1960)	39°18'36" 80°07'45"		10			
260	8	98(1960)	39°18'15" 80°08'15"		10			
261	8	98(1960)	39°16'30" 80°08'50"		6			
262	8	98(1960)	39°15'45" 80°10'00"		7			
263	8	98(1960)	39°16'17" 80°08'37"		5			
264	8	98(1960)	39°16'17" 80°08'15"		6			

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
265	8	98(1960)	39°15'38" 80°07'48"		5			
266	8	98(1960)	39°16'17" 80°07'32"		8			
267	8	98(1960)	39°17'05" 80°07'50"		7			
268	11	107(1961)	39°08'15" 80°22'40"		6			
269	8	109(1961)	39°12'08" 80°09'35"		5			
270	8	109(1961)	39°13'15" 80°08'15"		25			

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
271	8	109(1961)	39°13'55" 80°07'45"	Galloway Mine	115	4,000		Burning. 2000 x 200 x 60
272	10	109(1961)	39°10'35" 80°09'55"		4			
273	10	109(1961)	39°10'35" 80°09'35"		17			
274	10	109(1961)	39°10'10" 80°09'11"		7			
275	10	109(1961)	39°09'15" 80°08'50"		12			
276	13	110(1961)	39°09'55" 80°01'50"	Badger Coal Co. #14	8			Burning. 1500 x 1500 x 30 Impoundment 1/2 acre x 2 Two dumps. 2000 x 250 x 30 Burning

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
277	22	116(1967)	39°12'10" 80°19'08"		8			
278	11	118(1961)	39°03'35" 80°27'08"		5	80		
279	11	118(1961)	39°02'10" 80°26'55"		6			
280	14	120(1960)	39°02'35" 80°13'15"		37			Apparently is not a dump, but is a pasture. Field checked by W. Sheafer & J. Blair.
281	14	120(1960)	39°02'30" 80°11'20"		3			
282	14	120(1960)	39°02'35" 80°11'15"		2			

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
283	14	120(1960)	39°03'30" 80°11'15"		3			
284	14	120(1960)	39°05'46" 80°11'30"	Bethlehem Steel Co. No. 101	5	185		Abandoned Preparation Plant. Burning 1100 x 1200 x 50. Pond 300 x 60 x 5.
285	14	120(1960)	39°05'54" 80°11'00"	Bethlehem Steel Co. #1056	1			
286	14	120(1960)	39°05'52" 80°10'25"	Bethelehem Steel Co. #1056	3			
287	14	120(1960)	39°05'45" 80°09'35"	Bethlehem Steel Co. #105	4	200		
288	14	120(1960)	39°05'40" 80°09'20"	Bethlehem Steel Co. Century Mines	4	1,700		

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
289	14	120(1960)	39°05'30" 80°09'25"	Bethlehem Corp. Century Mines	6	150		
290	14	120(1960)	39°05'18" 80°09'25"		4	200		
291	14	120(1960)	39°05'08" 80°09'40"		3	200		
292	24	9(1953-69)	40°16'30" 79°40'08"		2			
293	24	9(1953-69)	40°16'15" 79°39'35"		3			
294	24	9(1953-69)	40°15'55" 79°39'38"		4			

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
295	22	115(1967)	39°12'45" 79°25'15"		48			*Outside of Basin
296	21	135(1968)	38°54'25" 79°42'50"		5			
297	1	12(1953-69)	40°12'45" 80°13'45"		23			*Outside of Basin
298	1	12(1953-69)	40°14'00" 80°11'00"		7			*Outside of Basin
299	29	45(1967)	39°54'30" 78°57'10"	W. E. Scurfield	6	156		No water impounded by bank, two slurry ponds, constructed of earth embankments, 150 x 100 x 30
300	29	44(1939)	39°54'00" 79°01'00"	Penn Pocahontas Coal Company				4 slurry ponds. No water impounded. 1000 x 200 x 60

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
301	29	32(1914)	40°00'00" 78°57'00"	PBS Coal, Inc. Cambria Prep. Plant				No dump as of June, 1972. **Outside of Basin
302	29	32(1914)	40°00'30" 79°56'00"	Denise Coal Co.				Filling Strip Pit. **Outside of Basin
303	29	38(1964)	39°51'30" 79°04'00"	Deckops Const. Co.				Filling Strip Pit **Outside of Basin
304	29	38(1964)	39°51'30" 78°58'45"	Cronor Inc.	6	89		Fill used to fill old mine portal 35 x 50 x 20 **Outside of Basin
305	2	38(1964)	39°52'40" 79°47'45"	George H. Magee Sapper Mine	10	489		1800 x 900 x 60
306	4	37(1964)	39°53'15" 79°53'30"		6	178		Bank is 1200 x 300 x 40

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
307	4	50(1964)	39°49'00" 79°54'45"		8	226		Abandoned. Max. Slope Angle = 40° Slide Potential. 500 x 300 x 100
308	14	15(1954-69)	40°09'50" 79°51'15"		12	963		Abandoned. Max. Slope Angle = 42° Slide Potential. 400 x 200 x 100
309	15	15(1954-69)	40°15'00" 79°40'55"	Helper Mine	14	555		Two Dumps. Abandoned. 400 x 150 x 50, 400 x 150 x 50.
310	8	85(1960)	39°24'02" 80°21'45"	Mountianeer Coal Co. Div. Consol. Coal Company Robinson Run #95	13	767		Slate dump and slurry pond. Dump is 500 x 500 x 75. Pond is 750 x 500 x 26 almost 9 acres.
311	7	73(1960)	39°26'25" 80°15'02"	Mountaineer Coal Co. Div. Consol. Coal Company Loveridge Mine	8	476		Dump 750 x 750 x 75 Impoundment is 9 acres.
312	14	130(1966)	38°54'37" 80°17'15"	Upshur Coal Co. Adrian Mine	9	222		Burning 2000 x 300 x 30 Pond 450 x 100 x 5 Angle of repose = 50°

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
313	8	97(1958)	39°19'10" 80°20'30"	Dawson Galloway Land Company	19	311		Burning. 2000 x 100 x 20
314	15	133(1969)	38°55'50" 79°57'43"	C. E. Hough Estate Norton Mine	5	185		Burning. Angle of Repose = 55° 2000 x 200 x 50
315	10	109(1961)	39°13'05" 80°10'20"	Ohio Mining Co. Ruby #4	6	400		Abandoned. 250 x 150 x 90
317	5	60(1958)	39°40'13" 80°16'05"	Eastern Assoc. Coal Company Federal #2	8	266		Clay construction. 120 x 70 x 40
318	3	36(1961)	39°59'30" 80°01'55"	Republic Steel Corp. Clyde #2	9	444		Burning. 1500 x 600 x 60.
319	24	9(1953-69)	40°16'05" 79°42'45"		3	111		Abandoned. Max. Slope Angle = 40° 700 x 300 x 50

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
320	15	15(1954-69)	40°14'15" 79°49'10"	Warden Mine	6	222		Abandoned. 400 x 100 x 50
321	15	15(1954-69)	40°14'40" 79°48'40"		5	370		Abandoned. 600 x 400 x 100
322	14	15(1954-69)	40°12'00" 79°51'50"	Ella Mine	4	415		Abandoned. Max. Slope Angle = 30o 400 x 200 x 140
323	4	36(1961)	39°58'45" 80°00'00"	National Mines Corp. E. Millsboro Mine	9	296		Bank is 300 x 150 x 40
324	27	39(1963)	39°59'53" 79°37'55"		3	185		Abandoned. 400 x 200 x 80
325	3	36(1961)	39°57'50" 80°02'55"	J & L Steel Corp. Gateway Mine	4	101		300 x 300 x 35

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
326	24	17(1964)	40°12'20" 79°31'30"	Helen Mining Co.	1	41		350 x 200 x 50 Max. Slope angle 30° 15" pipe used to carry spring water through the dump
327	23	8(1960)	40°16'40" 79°51'45"	Unknown	14	1,506		900 x 700 x 80 Abandoned Max. Slope angle 65° at steepest location. Slide can obstruct stream
328	24	9(1953-69)	40°16'05" 79°42'45"	Unknown	11	1,062		1200 x 400 x 80 Abandoned Max. Slope angle 70° - 80° where excavated Impoundment - 600 x 150 x 40
329	4	50(1964)	39°48'45" 80°00'00"	Unknown	1	42		Spoil Bank - 300 x 150 x 40
330	4	37(1964	39°53'15" 79°53'30"	Crucible Steel Mine Dump National Mine Corp.	22	2,087		1200 x 300 x 60 Spoil Bank 2000 x 300 x 60 Small rain pond on top
331	1	24(1954-69)	40°05'15" 79°55'15"	Unknown				Several small piles x 40 Spoil banks

MONONGAHELA RIVER BASIN
PRELIMINARY INVENTORY OF COAL REFUSE BANKS

Refuse Bank No.	Sub-Basin No.	U.S.G.S. Quad. No. & Date	Latitude Longitude	Owner and Name of Mine	Estimated Area (Ac.)	Estimated Volume (1000 C.Y.)	Estimated Waste Coal (1000 Tons)	Remarks
332	4	37(1964)	39°59'45" 79°58'15"	Vesta No. J & L Steel Corp.				All material processed at Vesta No.
333	1	6(1960-69)	40°18'40" 80°07'10"	Unknown	28	2,657		Abandoned. Max. Slope angle 35° 1500 x 800 x 80 - Bank

LOCATION OF LIMESTONE MINING OPERATIONS IN THE MONONGAHELA RIVER BASIN

Mine No.	Limestone Mine and Operator	Formation or Member	Chemical Analysis			Source	Map or Test No.	Thickness	Status
			%$CaCO_3$	%$MgCO_3$	%SiO_2				
1	Beaver Run Limestone Co., Appollo, Pennsylvania	Allegheny Group	N.A.	N.A.	N.A.	Ref. 1, p. 36	523A	N.A.	Active*
2	Agricultural Lime Co., Derry, Pennsylvania	Monongahela Formation	72.4	15.4	N.A.	Ref. 1, p. 36	521	N.A.	Active*
3	Penn Aggregates, Jeanette, Pennsylvania Penn Quarry	Monongahela Formation	N.A.	N.A.	N.A.	Ref. 1, p. 36	523	N.A.	Active*
4	Penn Aggregates, Jeanette, Pennsylvania, Irwin Strip Mine Operation	Monongahela Formation	N.A.	N.A.	N.A.	Ref. 1, p. 36	525	N.A.	Active*
5	Washington Stone Company, Washington, Pennsylvania	Upper Washington	72.9	3.8	N.A.	Ref. 1, p. 36	520A	36'	Active*
6	Commercial Stone Corp., Bellvernon, Pennsylvania (Lynn's Quarry)	Not Given	N.A.	N.A.	N.A.	Ref. 4, p. 26	N.A.	N.A.	Active*
7	Paul Kendi & Sons, Mt. Pleasant, Pennsylvania	Not Given	N.A.	N.A.	N.A.	Ref. 4, p. 19	N.A.	N.A.	Active*

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LOCATION OF LIMESTONE MINING OPERATIONS
IN THE MONONGAHELA RIVER BASIN

Mine No.	Limestone Mine and Operator	Formation or Member	Chemical Analysis			Source	Map or Test No.	Thickness	Status
			%$CaCO_3$	%$MgCO_3$	%SiO_2				
8	Connellsvile Bluestone Co., Scottdale, Pennsylvania	Loyalhanna (?)	49.3	1.3	46.0	Ref. 1, p. 22	241	N.A.	Active*
9	Somerset Lstne. Co., Inc. Somerset, Pennsylvania, Bakersville Quarry	Conemaugh Formation	N.A.	N.A.	N.A.	Ref. 1, p. 36	513	N.A.	Active*
10	Appalachian Stone, Div. of Martin-Marietta Corp., Cool Spring Quarry	Loyalhanna (?)	N.A.	N.A.	N.A.	Ref. 1, p. 22	245	N.A.	Active*
11	Keystone Lime Co., Springs, Pennsylvania	Greenbrier (?)	89.3	1.0	N.A.	Ref. 1, p. 36	515	N.A.	Active*
12	Appalachian Stone, Div. of Martin - Marietta Corp., Lake Lynn Quarry	Loyalhanna (?)	N.A.	N.A.	N.A.	Ref. 1, p. 22	250	N.A.	Active*
13	Appalachian Stone, Div. of Martin - Marietta Corp., Wymps Gap Quarry	Greenbrier (?)	N.A.	N.A.	N.A.	Ref. 5, p. 11	N.A.	N.A.	Active*
14	Spring Hill Quarry	Greenbrier	89.07	2.06	6.07	Ref. 2, p. 405	882	100'	Unknown

LOCATION OF LIMESTONE MINING OPERATIONS
IN THE MONONGAHELA RIVER BASIN

Mine No.	Limestone Mine and Operator	Formation or Member	Chemical Analysis			Source	Map or Test No.	Thickness	Status
			%$CaCO_3$	%$MgCO_3$	%SiO_2				
15	Greer, Greer, West Virginia	Greenbrier	88.3 82.4 87.7	1.54 5.85 1.67	8.85 10.01 8.59	Ref. 2, p. 405	878 879 881	17' 28' 17'	Unknown
16	Unnamed Quarry, 1.7 miles N.W. of Pine Bluff, West Virginia	Redstone	75.76 49.15	6.40 3.16	26.52 10.29	Ref. 2, p. 409	950 951	N.A. N.A.	Unknown
17	Unnamed Quarry 0.5 mile W. of Shinnston, West Virginia	Redstone	59.56	20.18	11.48	Ref. 2, p. 409	949	N.A.	Unknown
18	Quarry of Alpha Portland Cement Company, Manheim, West Virginia	Greenbrier	69.19 82.62	3.27 2.66	18.95 10.23	Ref. 2, p. 405	876 877	14' 12'	Unknown
19	Unnamed Quarry	Greenbrier	60.61	20.09	14.79	Ref. 2, p. 405	871	25'	Unknown
20	Unnamed Quarry on County Line E. of Nestorville, West Virginia	Greenbrier	80.16	1.75	13.23	Ref. 2, p. 405	870	45'	Unknown
21	Perry Lawson, 1.5 miles S.E. of Kirt, West Virginia	Greenbrier	89.19 80.40	2.07 2.26	7.71 12.62	Ref. 2, p. 405 p. 424	872 1356	17' N.A.	Unknown

LOCATION OF LIMESTONE MINING OPERATIONS
IN THE MONONGAHELA RIVER BASIN

Mine No.	Limestone Mine and Operator	Formation or Member	Chemical Analysis			Source	Map or Test No.	Thickness	Status
			%CaCO$_3$	%MgCO$_3$	%SiO$_2$				
22	Rosendolph Heirs, Just E. of Hendricks, West Virginia	Greenbrier	91.23	1.10	4.92	Ref. 2, p. 424	1349	N.A.	Unknown
23	Unnamed Quarry, S.R. 32, 3.5 miles N. of Harmon, West Virginia	Greenbrier	89.68 79.70 75.67 92.05 80.20 91.07	6.39 2.63 2.27 1.39 1.41 2.20	3.49 14.92 20.16 5.68 18.39 6.15	Ref. 2, p. 404 p. 404 p. 404 p. 404 p. 405 p. 405	860 861 864 866 867 868	17' 15' 4' 21' 47' 65'	Unknown
24	Unnamed Quarry Just N. of Harman, West Virginia	Greenbrier	84.36	1.98	12.14	Ref. 2, p. 404	859	50'	Unknown
25	Quarry of Tygart Valley Assoc., Near Valley Bend, West Virginia	Greenbrier	93.55 88.96	1.59 2.23	4.35 7.92	Ref. 2, p. 404 p. 404	844 846	22' 17'	Unknown
26	Not Given	Greenbrier	90.35	2.08	6.12	Ref. 3, p. 10	22	N.A.	Active**
27	Not Given	Greenbrier	86.55	6.21	4.90	Ref. 3, p. 10	23	24'	Active**
28	Not Given	Mauch Chunk	70.65	.24	15.00	Ref. 3, p. 11	25	N.A.	Active**

LOCATION OF LIMESTONE MINING OPERATIONS IN THE MONONGAHELA RIVER BASIN

Mine No.	Limestone Mine and Operator	Formation or Member	Chemical Analysis			Source	Map or Test No.	Thickness	Status
			%$CaCO_3$	%$MgCO_3$	%SiO_2				
29	Not Given	Greenbrier	82.73	3.60	N.A.	Ref. 3, p. 11	26	15'	Active**
30	Not Given	Greenbrier	95.01	1.24	2.69	Ref. 3, p. 11	28	N.A.	Active**
31	Not Given	Greenbrier	N.A.	N.A.	N.A.	Ref. 3, p. 11	37	N.A.	Active**
32	Not Given	Greenbrier	N.A.	N.A.	N.A.	Ref. 3, p. 11	38	N.A.	Active**
33	Not Given	Redstone	85.63	2.28	8.71	Ref. 2, p. 409	944	N.A.	Unknown

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1. O'Neill, B.J., Jr., 1964, Atlas of Pennsylvania's Mineral Resources, Part I - Limestones and Dolomites of Pennsylvania: Pa. Geol. Surv. Bull. M-50.

2. McCue, J. B., Lucke, J.B., and Woodward, H. P., 1939, Limestones of West Virginia: W. Va. Geol. Surv. Vol. XII, 560 p.

3. Kusler, D. J., and Corre, H. A., 1968, Limestone Resources In Western West Virginia: U.S. Bur. of Mines Inf. Circ. 8369, 76 p.

4. Yeloushan, C. C., 1968, The Mineral Industry of Pennsylvania in 1966: Pa. Geol. Surv. Inf. Circ. 59, 26 p.

5. Pennsylvania Dept. of Transportation, Revised April, 1972, Tentative List of Producers of Coarse Aggregate: Bull. 13, 54 p.

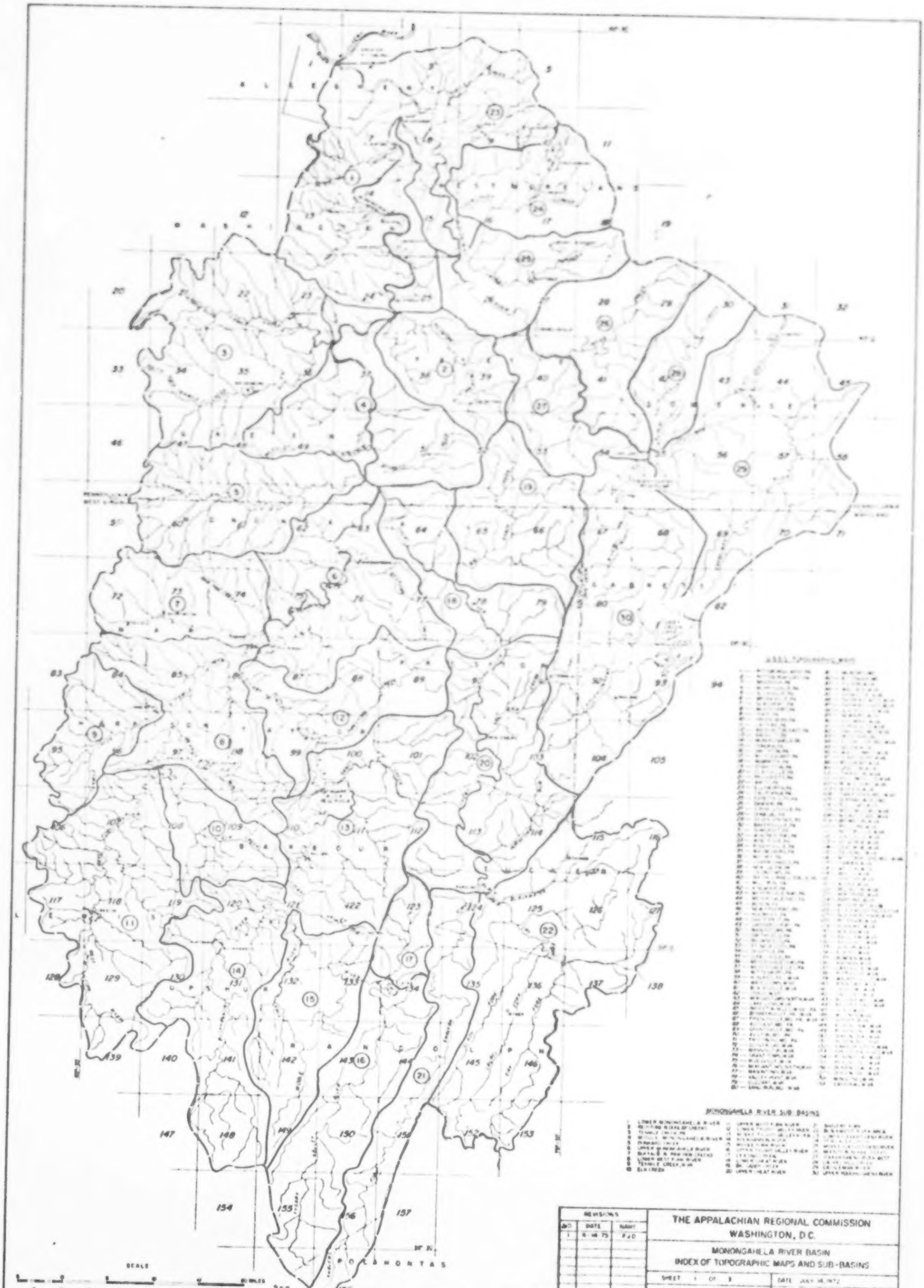
Footnotes: *Active as of Jan., 1963
**Active During Period 1948-1968

MAP SHEETS

MONONGAHELA RIVER BASIN, INDEX OF TOPOGRAPHIC MAPS AND SUB-BASINS

MONONGAHELA RIVER BASIN, LOCATION OF COAL REFUSE AND POWER PLANTS

MONONGAHELA RIVER BASIN, OUTCROP MAP OF THE GREENBRIER LIMESTONE


MONONGAHELA RIVER SUB-BASINS
SCALE
MILES
KILOMETERS
POCAHONTAS

REVISIONS		
NO.	DATE	NAME
1	6-16-75	F.J.D.

THE APPALACHIAN REGIONAL COMMISSION
WASHINGTON, D.C.

MONONGAHELA RIVER BASIN
INDEX OF TOPOGRAPHIC MAPS AND SUB-BASINS

SHEET 1 OF 3
SCALE 1:675,000
DATE JULY 18, 1972
MICHAEL BAKER, JR., INC.
Consulting Engineers
BEAVER PENNSYLVANIA
DRAWN W.E.S.
TRACED W.E.S.
CHECKED R.O.M.
FILE 72-83/RFC-707

APPROVED F.J.D.
DATE 7-25-72
APPROVED ENGINEERING
DATE

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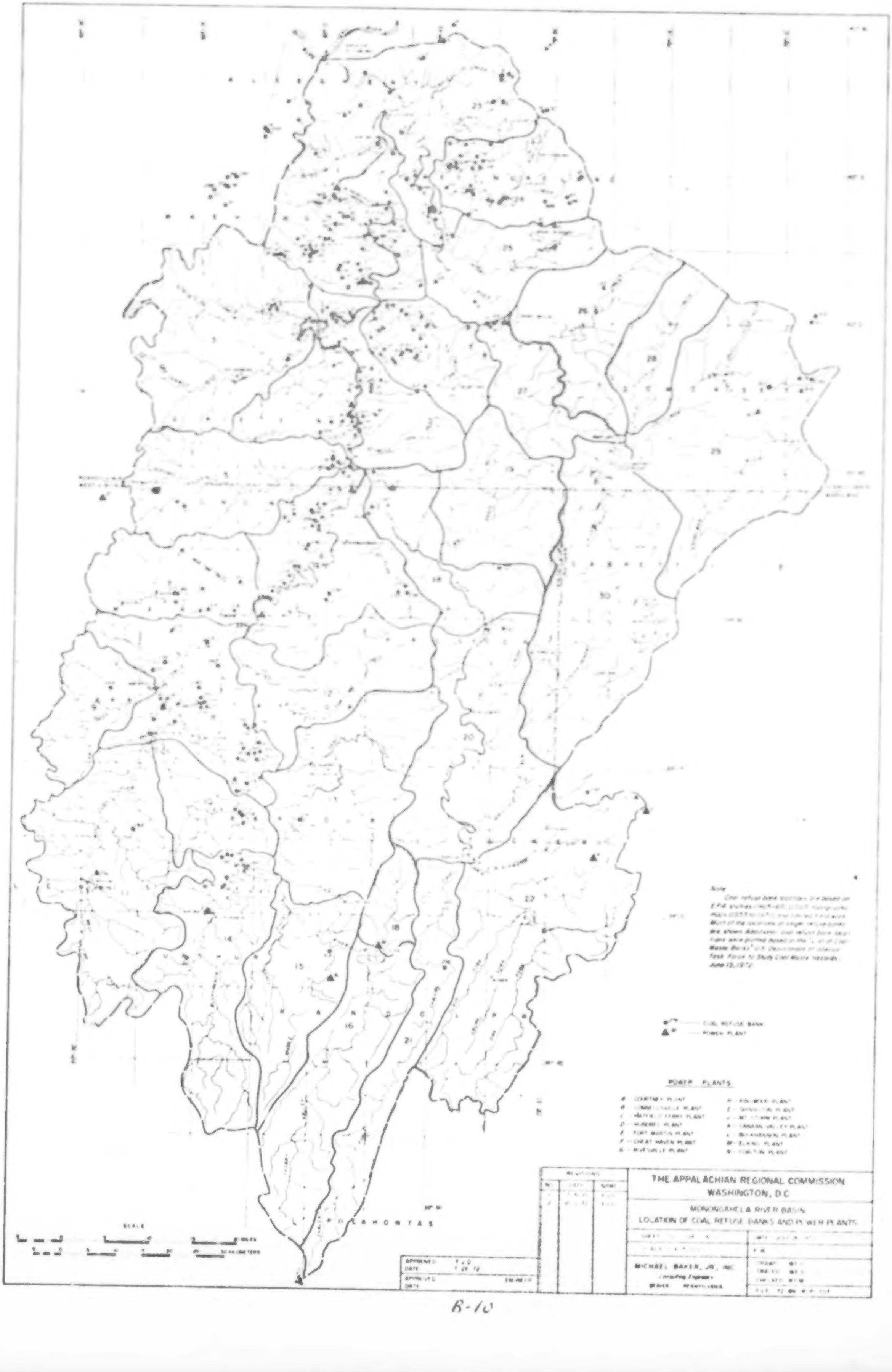


Note

Coal refuse bank locations are based on E.P.A. studies (1967-69), U.S.G.S. topographic maps (1955 to 1971), and limited field work. Most of the locations of larger refuse banks are shown. Additional coal refuse bank locations were plotted based on the "List of Coal Waste Banks" U.S. Department of Interior Task Force to Study Coal Waste Hazards, June 15, 1972.

● — COAL REFUSE BANK
▲ — POWER PLANT

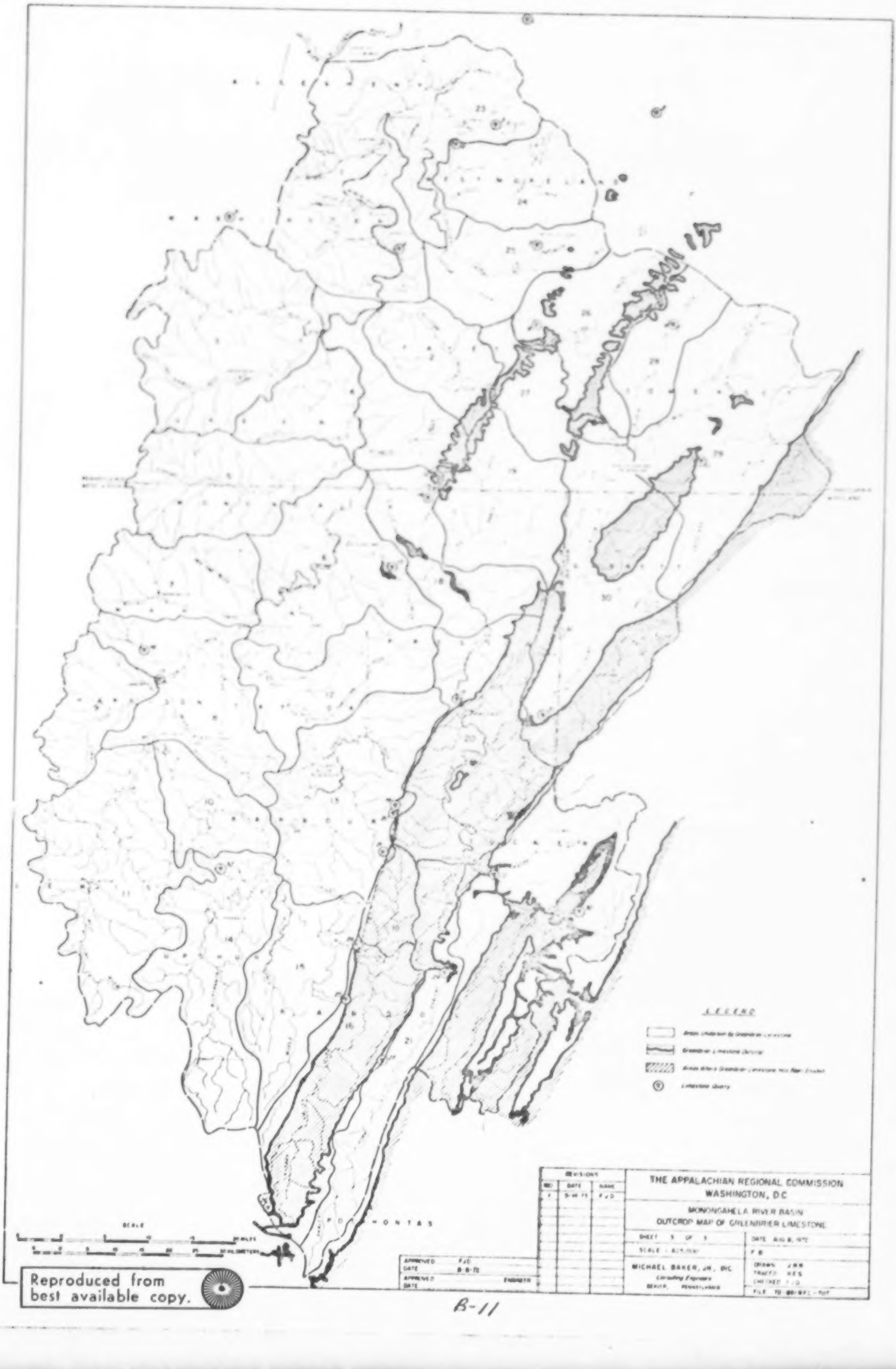
POWER PLANTS

A — COURTNEY PLANT
B — CONNELLSVILLE PLANT
C — HATFIELD FERRY PLANT
D — [illegible] PLANT
E — FORT MARTIN PLANT
F — CHEAT HAVEN PLANT
G — RIVESVILLE PLANT
H — [illegible] PLANT
I — HARRISON PLANT
J — MT. STORM PLANT
K — CANAAN VALLEY PLANT
L — BUCKHANNON PLANT
M — ELKINS PLANT
N — COALTON PLANT

THE APPALACHIAN REGIONAL COMMISSION
WASHINGTON, D.C.

MONONGAHELA RIVER BASIN
LOCATION OF COAL REFUSE BANKS AND POWER PLANTS

MICHAEL BAKER, JR., INC.
Consulting Engineers
BEAVER PENNSYLVANIA


MONONGALIA
POCAHONTAS
SCALE
0 5 10 15 20 MILES
0 5 10 15 20 25 30 KILOMETERS

LEGEND

- ☐ Areas Underlain by Greenbrier Limestone
- ━ Greenbrier Limestone Outcrop
- ▨ Areas Where Greenbrier Limestone Has Been Eroded
- ⓥ Limestone Quarry

REVISIONS		
NO.	DATE	NAME
1	9-10-73	F.J.D.

THE APPALACHIAN REGIONAL COMMISSION
WASHINGTON, D.C.

MONONGAHELA RIVER BASIN
OUTCROP MAP OF GREENBRIER LIMESTONE

SHEET 5 OF 5
SCALE 1:625,000
DATE AUG 8, 1972
F.B.

MICHAEL BAKER, JR., INC.
Consulting Engineers
BEAVER, PENNSYLVANIA

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